

بسم الله الرحمن الرحيم

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*Faculty of Engineering and Architecture*  
*Department of Civil Engineering*

## **Assessment of Water Supply System** **Case Study (Elfasher – North Darfur)**

*A Thesis Submitted in Partial Fulfillment of the Requirement for*  
*The degree of Master of Science in Water Resources Engineering*

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# DEDICATION

*To my father's Soul*

*To my family*

## **Acknowledgement**

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## ***Abstract***

This study was conducted on North Darfur State Water resources, taking El fasher water supply as a case-study.

The study includes review on the available water resources for the state, either surface or ground water. The surface water is from surface runoff generated by rainfall, the groundwater resources are either alluvial aquifers: Wadi Kutum and Wadi El Ku, or the Nubian Sandstone aquifer. The study also gives review on the water supply systems known in the state as: traditional, Hafirs and Dams, Hand dug wells, Hand Pumps, which were introduced by the UNICEF since 1992, and Water yards.

The available water resources for El fasher town are surface water from rainfall and ground water from Shagera and Sag El Naam basins.

The state suffers from acute deficit of water due to low rainfall and short duration of surface runoff. The study aims to allocate a suitable option which will provide Elfasher Town with adequate quantity of water for the coming 20 years after which the consumption is projected to be 55000 m<sup>3</sup> /d.

The Golo dam and the two Hafirs as well as Shagera boreholes which were now the essential sources of water for Elfasher town are viewed to secure a sustainable supply source for the rural people living in the area.

A rural water supply plant using slow sand filtration technique is proposed to treat the surface water collected behind Golo dam and the two Hafirs, it is to serve about 14000 people for a life time of 10 years. The system is suggested to be of common water points at suitable sites, with the possibility of making house connection in the future.

A FORTRAN program was made to design a pipeline 10km long (the proposed distance of the farthest stand post) and the pump required. The cost of the rural treatment plant is estimated to be about 400,000 USD, the community has to participate with the government in affording this amount as well as in running it.

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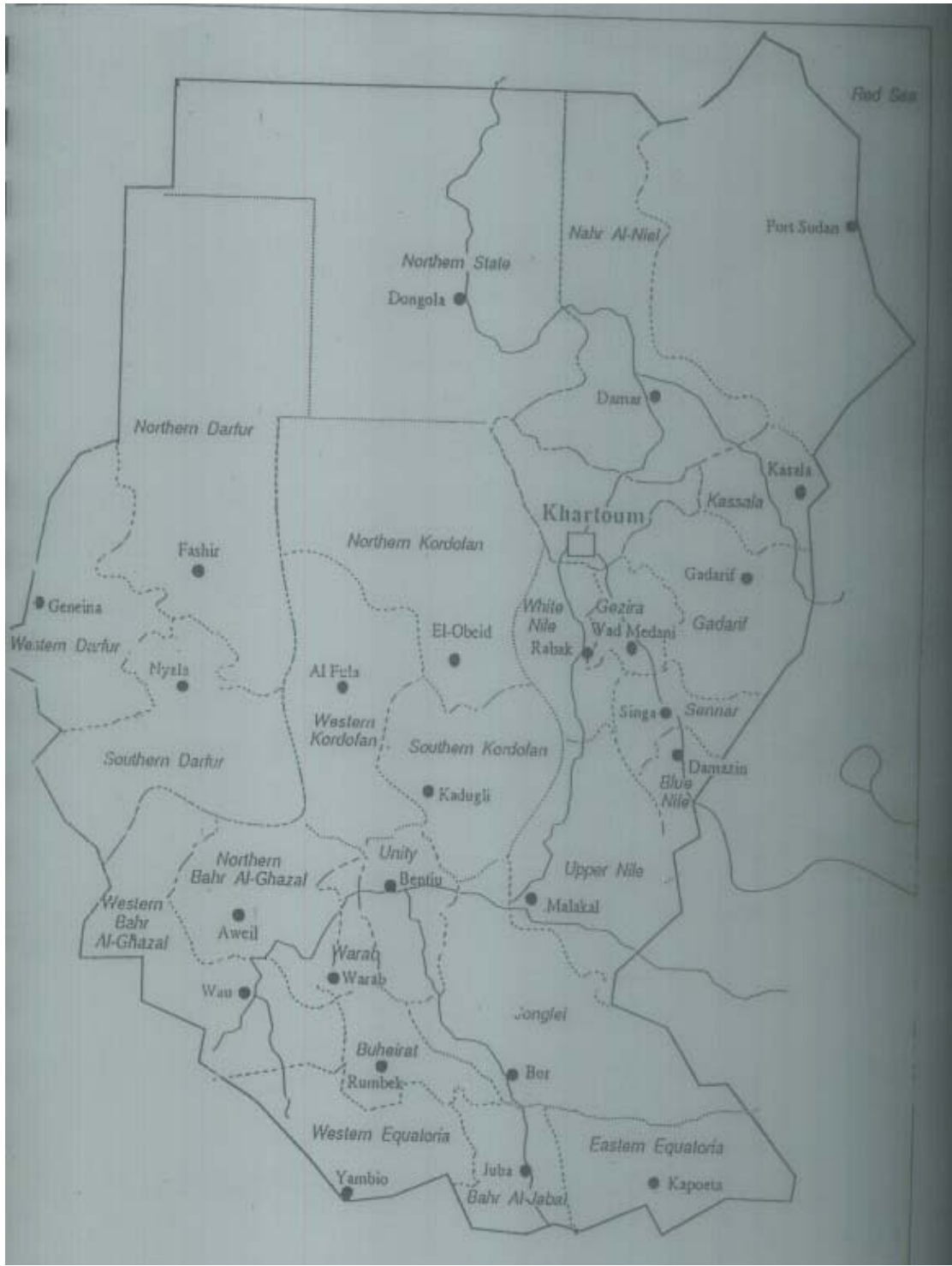
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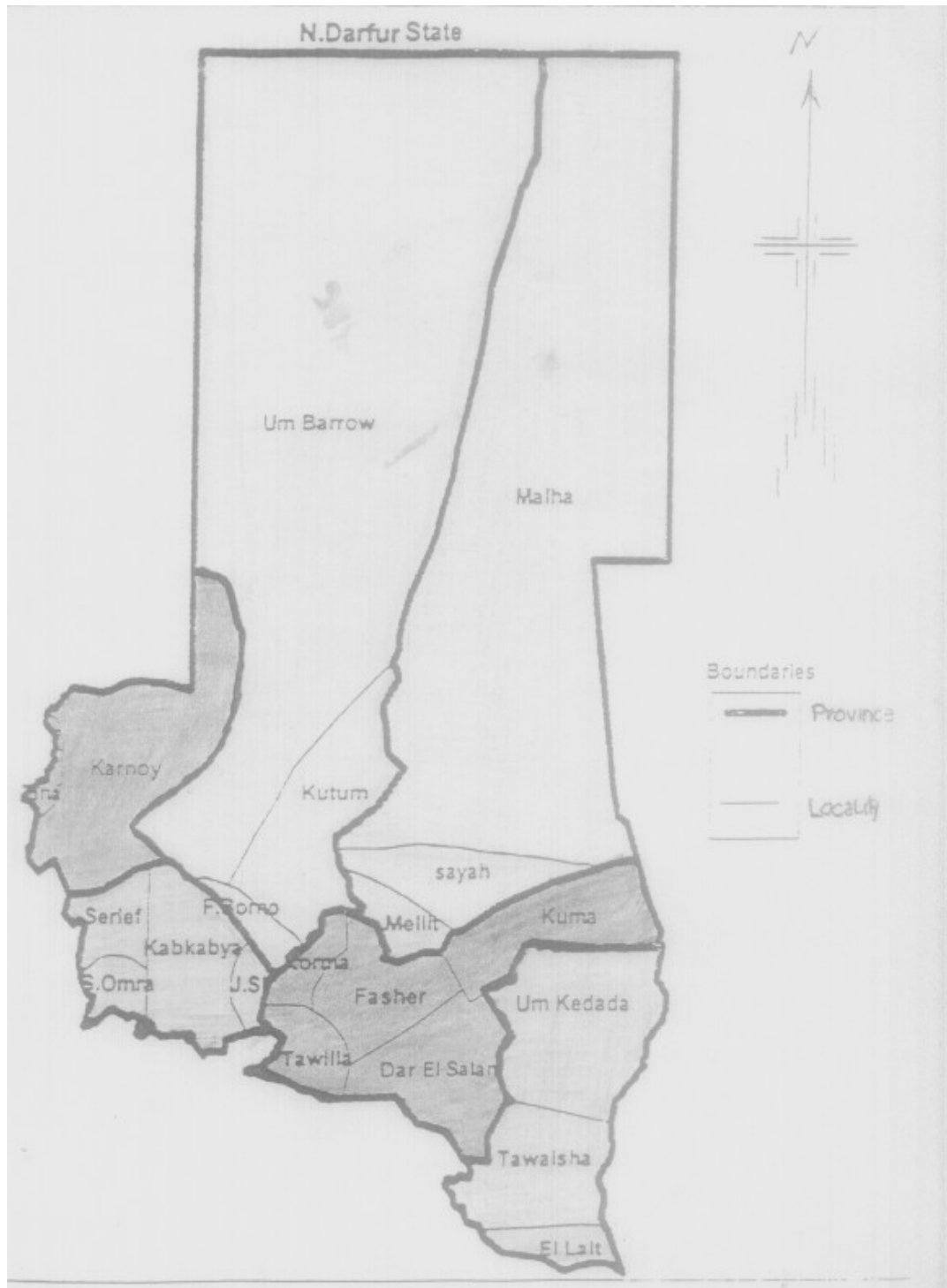
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**Fig. (1.1)**  
**States of Sudan**



**Fig. (1.2)**

**North Darfure State**



## **Chapter one**

### ***Introduction***

#### ***1.1 General***

Water is the most important natural resource in the world since without it life cannot exist, and most industries cannot operate. Although human life can exist for many days without food, the absence of water for only a few days has fatal consequences. The presence of a safe and reliable source of water is thus an essential prerequisite for the establishment of a stable community.

Absence of such source leads communities to move from one place to another as demand of water exceeds its availability. Sources of water are often jealously guarded to keep water rights, also agricultural development has been hindered by interference with water supplies as part of the conflict between land owners and settlers, this is happening in many countries. Other conflicts in relation to water supplies may arise because of the effects which human and industrial wastes can have on the environment. This means that the importance of water as a natural resource which requires careful management and conservation must be universally recognized.

#### ***1.2 Study Area***

##### ***1.2.1 North Darfur State***

North Darfur State is located in the north western corner of the Sudan Fig (1.1), it is bounded by longitudes  $22^{\circ} 50'$  and  $27^{\circ} 30'$  East and latitudes  $11^{\circ} 45'$  and  $20^{\circ} 00'$  North with total area of about 292,000 sq km, inhabited by 1.6 million persons of whom about 70% are rural settlers and nomads.

Administratively the state is formed of six Mahallias: Elfasher, Umm Kaddada, Malliet, Kutum, Kebkabia, Elteena and another mahallia called Elwaha which has not defined borders, it is concerned with the non settled people most of them are nomads, and the commissioner office is at Elfasher, capital of the state.

The landscape of the area is an undulating topographic plain with high lands and mountainous terrain of Jebel Marra Massive in the south western parts of the state, where most of the Khors and Wadis originate mainly due to relatively high rainfall coupled with the soil nature and the steep topographic gradient, the area is covered with dense vegetation. However isolated hills, inselbergs and longitudinal sand-dunes make great portion of the landscape. The Qoz and the desert land cover more than 60% of the state especially the north and the north eastern parts. Due to the advancement of the sand dunes southwards by northerly winds enhanced by drought episodes, most of the wadi courses have been detached and buried with sand.

The climate of the North Darfur State is a typical desert climate with daily temperature of 40<sup>0</sup>C in summer and drops to 10<sup>0</sup>C during winter. The dry season extends from end of October to June, followed by a raining season from July to September. The northern parts of the state are very dry and vulnerable to desertification resulting from drought events, removal of trees and land clearance for rain fed farming, average rainfall ranges between 80-150 mm/year. The south western parts of the state lie within the high lands of Jebel Marra Massive, where the climate is characterized by poor savanna wood land with average rainfall ranges between 150-300 mm/year. Thus the main features of the state climate is characterized by:

- Extensive water deficit due to low rainfall.
- High evaporation rates
- Short duration of runoff.

The main economic income of the rural people in North Darfur is from agriculture and livestock, whose increasing number will make additional burden on the existing water sources and deteriorating their efficiencies.

### ***1.2.2 Elfasher Town:***

Elfasher Town, the capital of North Darfur state is situated at latitude 13<sup>0</sup> 37'N and longitude 25<sup>0</sup> 22' E at an altitude of approximately 740 m above mean sea level.

The town is build around a shallow depression known as Fula (Rahad Tendelti) which collects and stores surface water from wadi Halluf and Wadi Siwalinga whose courses run from north and east to the south west of the town – and drainages from the town during the wet season. Most of the administrative and military establishments and government houses are lying to the west of the Fula, the main residential and commercial areas lying to the north and east.

The town is divided into north and south sectors constituting 86 quarters (Hai) (Elfasher locality – Mahalia) and occupied by 200.000 persons.

Elfasher town lies in tropical semi-arid climatic region; the average rainfall over the last five decades is about 287 mm/annum. Since 1970s the trend of the annual rainfall runs below the average, that is due to the frequent Sahelian drought events that hit the area, enhancing the process

of desertification and force rural people to settle on the extremes of the town.

The average maximum monthly temperatures vary from 32<sup>0</sup>C in Dec. and Jan. to 40<sup>0</sup>C in May and June while the average minimum monthly temperatures lie between 10 and 20<sup>0</sup>C.

Industrial activities in the town are small represented only in ground nut processing and traditional tannery; however these industries are constrained by the shortage of water.

Elfasher is the most important town in the state since it is an administrative and commercial centre whose services and benefits are to be available, for the surrounding area such as the airport, health and education services. Agricultural and animal husbandry are the principal economic activities of the region. Elfasher provides a market for produce and livestock.

The system of power supply for the town is inadequate and was provided by diesel generators. Sanitary disposal in the town is mainly in the form of pit latrines and represents about 75% of the total houses. They have little danger of pollution of water resources, the only shallow wells in Elfasher are around the Fula where no houses exist.

The most prevalent diseases which are related to water shortage or born in water ranked as follows:

- Malaria.
- Diarrhea diseases (bacillary and amoebic dysenteries, giardiasis and typhoid fever).

- Eye infections
- Schistosomiasis (bilharzias).
- Childhood diseases (cough, measles)
- Goiter
- Malnutrition diseases.
- Tuberculosis.

Most of the above mentioned diseases are caused directly or indirectly by poor water supplies or environmental pollution. (Information is given by the statistic health authorities, Elfasher).

### ***1.3 Identification of the problem***

North Dar fur State climate is characterized by extensive water deficit, high evaporation rates and short durations of surface runoff.

Resources other than surface water should be searched for in order to secure adequate water supplies for the communities.

The importance of water as a natural resource for life to exist and for most of the industries to operate implies that presence of safe and reliable source is necessary for the establishment of a stable community.

### ***1.4 Objectives of the study:***

- 1- Assessment of Elfasher water supply. (quantity and quality).
- 2- Proposing options for water supply of Elfasher town.
- 3- Design of a water supply system to satisfy the need of rural areas around Elfasher including software application.
- 4- Cost estimate of the proposed project.



### ***1.5 Outline of the Dissertation***

This study has come into five chapters: chapter one is an introduction giving general information about the study area North Darfur State and Elfasher town, identification of the problem and the objectives of the study. Chapter two is a literature review on groundwater flow, flow through pipes available recourses of water in the state and the systems used for supplying the water. Available water resources for present and future supply of Elfasher tow along with a history about the town water supply are also viewed here. The chapter also gives literature review about the importance of water treatment, the water-related disease, water quality standards and components of a plant for treating the water through slow sand filtration. Chapter three describes methodology of the study. Results are discussed in chapter four, and chapter five accounts for conclusion and recommendations.

## **Chapter Two**

### ***2. Literature Review***

#### ***2.1 Ground Water Flow***

Groundwater can be defined as that portion of water beneath the earth's surface that can be collected by wells or galleries in usable qualities. It is commonly understood to mean water occupying all the voids within a geologic stratum; it provides a very important source of water supply in many parts of the world, particularly in arid and semi-arid regions most often affected by droughts. Ground water constitutes one portion of the earth's circulatory system known as the hydrologic cycle and represents 97% of the directly available fresh water on the earth.

Practically all ground waters originate as surface water, the main sources of natural recharge are from:

- Precipitation
- Lakes
- stream flow
- Reservoirs

Artificial recharge occurs from:

- excessive irrigation
- seepage from canals

Water within the ground moves downward through the unsaturated zone under the action of gravity, while in the saturated zone it moves in a direction determined by the surrounding hydraulic situation.

Discharge of groundwater occurs when water emerges from underground as:

- Flow into surface water bodies (streams, lakes, oceans, ... )
- Springs

Groundwater near the surface of the earth may return to the atmosphere by:

- Evaporation from within the soil
- Transpiration from vegetation.

Pumping from wells is the major artificial discharge of groundwater.

### ***2.1.1 Rock properties Affecting Groundwater Flow:***

#### **a) Aquifers:**

An aquifer is defined as a formation that contains sufficient saturated permeable material to yield significant quantity of water to wells and springs (Todd, Groundwater Hydrology)

Aquifers may be overlain or underlain by a confining bed or an impermeable material, so aquifers are either confined or unconfined depending on the absence or presence of the water table.

#### **b) Porosity:**

Those portions of rock or soil not occupied by solid mineral matter can be occupied by groundwater. Such spaces are known as voids, pores or pore space.

The porosity of soil is a measure of the contained voids and is expressed as the ratio of the volume of pores to the total volume.

The term effective porosity refers to the amount of inter connected pore space available for fluid to flow.

**c) Storage coefficient:**

Water recharged to or discharged from an aquifer represents a change in the storage volume within the aquifer, so storage coefficient or storativity is defined as the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of head normal to the surface. (Todd, Groundwater Hydrology)

**d) Permeability:**

The permeability of a rock or soil defines its ability to transmit a fluid.

**e) Hydraulic conductivity:**

It is a measure of the permeability of a media; it is an important constant in groundwater flow equations.

***2.1.2 Groundwater Movement:***

Groundwater in its natural state is invariably moving, this movement is governed by established hydraulic principles. Flow through aquifers, most of which are natural porous media, can be expressed by Darcy's law.

Darcy, a French hydraulic Engineer (1856) (Todd) investigated the flow of water through horizontal beds of sand to be used for water filtration.

Darcy's law states that the flow rate through porous media is proportional to the head loss and inversely proportional to the length of the flow path.

The experimental verification of Darcy's law can be performed with water flowing at a rate  $Q$  through a cylinder of cross-sectional area  $A$  packed with sand and having piezometers at distance  $L$  apart Fig.(2.1).

$$Q \propto h_L$$

$$Q \propto 1/L$$

Introducing a proportionality

Constant  $k$  then

$$Q = -kA (h_L/L)$$

expressed in general terms:

$$Q = -kA (dh/dL)$$

$$\therefore Q/A = v = -k (dh/dL)$$

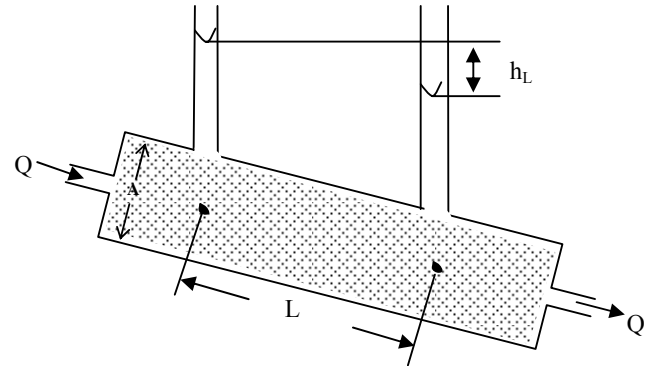
where  $v$  is the Darcian velocity

$k$  is the hydraulic conductivity

$(dh/dL)$  is the hydraulic gradient

-ve sign indicates that the flow of water is in the direction of decreasing head.

**Fig. (2.1)**  
**Verification of Darcy's Law**



Darcy's law serves as a basis for present day knowledge of groundwater. Flow analysis and solution of problems relating to Groundwater Management and well hydraulics began after Darcy's work (Todd, Ground Water Hydrology)

### **Hydraulic conductivity:**

A medium has a unit hydraulic conductivity if it will transmit in unit time a unit volume of groundwater through a cross-section of unit area at right angle to the direction of flow, under a unit hydraulic gradient:

$$K = - (v/dh/dl) = - [m/d] / [m/m] = m/d$$

**Transmissivity T:**

Is defined as the rate at which water is transmitted through a unit width of aquifer under a unit hydraulic gradient

$$T = kb = (m/d) (m) = m^2/day$$

b is the saturated thickness of the aquifer

**2.2 Flow of water through pipes**

A pipe is a closed conduit (generally of circular section) which is used for carrying fluid under pressure. Flow may be laminar in which paths taken by individual particles do not cross one another and move along well defined paths or may be turbulent in which particles move in zig zag way. Laminar and turbulent flows are characterized on the basis of Reynolds No. Re i.e.

if  $Re = 2000$  flow in pipe is laminar

$Re > 4000$  flow in pipe is turbulent

For  $Re$  between 2000 and 4000 flow may be laminar or turbulent

$$Re = VD / \nu$$

Where

$Re$  the Reynolds No.

$V$  = velocity of flow through pipe

$D$  = pipe dia.

$\nu$  = kinematic viscosity of water.

The flow in a pipe is termed pipe flow only when the fluid completely fills the cross-section and there is no free surface of fluid (R.K. RAJPUT, 2000, Fluid Mech.).

**Loss of energy in pipes:**

When water flows in a pipe, it experiences some resistance to its motion due to which its velocity and ultimately the head of water available is reduced. The loss of energy is classified into major and minor losses.

- Major losses  
    This loss is due to friction
- Minor losses
  - Due to change in x-section
  - bent in pipe
  - an obstruction
  - fittings

The major energy losses which are due to friction are calculated by:

1. Darcy Weisbach formula (used for loss of head through pipes).
2. Chezy's formula (used for loss of head for flow through channels).

Darcy Weisbach formula is given by:

$$h_f = f (L/D) (V^2/2g)$$

Where

$h_f$  = loss of head due to friction.

$f$  = coeff. of friction (a function of Reynolds No.)

$L$  = length of pipe.

$V$  = mean velocity of flow

$D$  = diameter of pipe

$g$  = acceleration due to gravity

## ***2.3 Treatment of water:***

### ***2.3.1 Importance of treatment:***

Waters often have highly complex compositions, modifications to the compositions are usually necessary through a variety of treatment processes to deal with the range of contaminants likely to be encountered such as:

- 1- Floating or large suspended solids like leaves, branches, etc.
- 2- Small suspended and colloidal solids like clay and silt particles, micro-organisms.
- 3- Dissolved solids: alkalinity, hardness, organic acids
- 4- Dissolved gasses: Carbon dioxide, hydrogen sulphide
- 5- Immiscible liquids: oils and greases

There are three main classes of treatment processes.

- 1- Physical processes which depend essentially on physical properties of the impurity e.g. particle size, specific gravity, viscosity, example of such processes are:
  - Screening.
  - Sedimentation
  - Filtration and gas transfer
- 2- Chemical processes which depend on chemical properties of an impurity or which utilize the chemical properties of added reagents, examples:
  - Coagulation.
  - Precipitation
  - Ion exchange
- 3- Biological processes which utilize biochemical reactions to remove soluble or colloidal impurities, usually organics.



In some situations, a single treatment process may provide the desired change in composition, but in most cases it is necessary to utilize several processes in combination.

Water will require treatment for many reasons; most important is the necessity of removing the germs. For palatability it must be free from unpleasant tastes and odors, it should be aesthetic and useful for domestic needs as well as for a wide variety of industrial purposes.

***Table (2.1)***  
***Impurity removed after each treatment process:***

<b>Process</b>	<b>Impurity removal</b>
1- Aeration	Tastes and odors removal, oxygen deficiency
2- Screening	Floating matter
3- plain sedimentation	Large suspended solids
4- coagulation	Fine particles
5- Filtration	Colloidal particles
6- Activated carbon	Elements causing taste & odors
7- softening	Hardness
8- disinfection	Living organisms including pathogens.

### ***2.3.2 Water related Diseases***

Because of the essential role played by water in supporting human life it has, if contaminated, great potential for transmitting a wide variety of diseases and illnesses. There are about two dozen infectious diseases, the incidence of which can be influenced by water; they may be due to viruses, bacteria, protozoa or worms.

Table (2.2) shows classification system for water elated diseases which differentiates between the various forms of infections and their transmission routes (Principles of water quantity control, T.H.Y. TEBBUTT)

**Table (2.2)**

<b>Disease</b>	<b>Type of water relationship</b>
1- Cholera	Water-borne
2- infections hepatitis	
3- leptospirosis	
4- paratyphoid	
5- tularemia	
6- typhoid	
7- Amoebic dysentery	Water-borne or water-washed
8- Bacillary dysentery	
9- Gastroenteritis	
10- Ascariasis	Water-washed
11- Conjunctivitis	
12- Diarrhoeal diseases	
13- Leprosy	
14- Scabies	
15- Skin sepsis and ulcers	
16- Tinea	
17- Trachoma	Water-based
18- Guinea worm	
19- Schistosomiasis	Water-related insect fever
20- Malaria	
21- onchocarciasis	
22- Sleeping sickness	
23- yellow fever	

### ***2.3.3 Components of a water treatment plant:***

It is often necessary to give the water some form of pretreatment to improve its quality and reduce the load of suspended material before it enters the filter unit. After completion of the filtration process, practically all bacteria will have been removed. As an additional safeguard the water is usually chlorinated. The chlorination process will eliminate the bacteria and viruses which may have slipped and provide some protection against subsequent contamination in the water distribution system.

A complete water treatment plant in which slow sand filtration is applied contains mostly the following processes:

- 1- Pretreatment (Plain sedimentation).
- 2- Slow sand filtration.
- 3- Chlorination
- 4- Distribution system

#### **(i) Pretreatment**

The most important drawback of slow sand filtration process is its vulnerability to excessive turbidity which causes rapid clogging of the filter bed. Clogging requires frequent cleaning activities and this is not acceptable. Pretreatment can then offer a solution. Various types have been advantageously used in small community water supply plants; one of them is plain sedimentation. It can be applied when water contains a large amount of settleable material which should not be allowed to enter the filter.

When water passed through a sedimentation tank, its velocity reduced enabling a large proportion of suspended silts to sink to the bottom of the tank. So emptying the tank from time to time is needed to remove the sediments. The frequency of cleaning depends on the rate of built up of silts.

## **ii) Slow sand filtration.**

Water from the plain sedimentation tank does not satisfy the drinking water standards and is not safe or palatable. Further treatment is required; it is to be passed to a slow sand filter, which consists of an open water tight tank of suitable dimensions. The filtering media is a sand bed of about one meter thickness, 0.35 mm effective diameter and uniformity coefficient of about 1.75, supported by a gravel layer of 40 -60 cm thickness, size from 0.3 to 7.5 cm placed in layers with the biggest particles at the bottom resting on top of a system of under drains which collect the filtered water. Fig (4.2)

Under normal operation water is fed continuously onto the top of the filter and is allowed to percolate slowly through the sand bed, during this passage, the quality of the water improves considerably. After some time a thin layer will form on the surface of the bed as a filter skin, it consists of a great variety of biologically active micro-organisms which break down organic matter. The filter will get clogged after some months decreasing the filtration capacity; it can be restored through cleaning the filter by scraping off the top few cms of the filter bed including the filter skin.

Resanding becomes necessary when successive scrapings have reduced the sand bed thickness to less than 70 cms.

## **iii) Chlorination.**

Although a well operated slow sand filter provides a water safe in bacteriological quality, chlorine has to be added before putting the water into the supply. Chlorine has the property of killing micro-organisms such as bacteria, and provides protection against possible defects in the

filters or pollution in the distribution network, it also prevents after growth of bacteria in the distribution system.

The amount of chlorine added must be carefully controlled and adjusted so that there is a residual in the water entering the distribution system. Chlorine does not act instantaneously; it needs contact time after which the water will be distributed.

After filtration the water flows to a low level tank of round or rectangular concrete or masonry box, completely covered to prevent the clear water from being polluted.

The clear water tank serves the following purposes:

- It collects and stores the treated water which makes it easy to be pumped into the supply.
- Provides the necessary time needed for the contact of the chlorine with water to make disinfection effective.

Cleaning of the tank must be done regularly, the tank should be emptied, silt removed and carefully checked for possible leakage.

#### **iv) Water distribution:**

Once treatment has been completed, the water has to be delivered to the consumers. It has to be distributed to the users through underground pipes to public stand posts situated at suitable distances; the system may have house connections as well. The water from the clear water tank may be pumped directly into the supply system, but it is preferable to provide a distribution reservoir on an elevated position for:

- Short term variation in demand can be met without alerting the pumping rate.
- Adequate and uniform pressure is maintained in the distribution area throughout the day.
- Short breakdown of pumps can be accommodated without interrupting the supply.

The distribution system should make water constantly available under pressure to each house in the community as well as in the public stand posts especially in rural areas where scattered housing makes individual house connections expensive because of the long lengths of pipe required. The following points should be considered for the operation and maintenance of public stand posts:

- 1- Number and location of the stand posts should be adequate to keep walking distance to a minimum.
- 2- Strong and durable material should be used for the construction.
- 3- Provision should be made for spill drainage.
- 4- Intermittent operation of the water supply system should be avoided as this may lead to excessive spillage due to taps left open while no water was coming out.
- 5- The importance of promptly repairing damage to reduce waste of water.
- 6- The essential role of community participation in the maintenance of the stand posts and its surroundings.

#### ***2.4 Water quality Standards:***

Water is essential to sustain life, and a satisfactory supply must be made available to consumers. Every effort should be made to achieve a drinking water quality as high as practicable. So protection of water supplies from contamination is the first line of defense.

WHO stated guide lines for drinking water quality aiming to the protection of public health; they have been widely used as a basis for setting national standards to ensure the safety of public water supply. The guide line values recommended are not mandatory limits, such limits should be set by national authorities in the context of local or national, environmental, social, economic and cultural conditions.

Source protection is the best method of ensuring safe drinking water, it is better than treating a contaminated water supply to render it suitable for consumptions. Water source must be protected from contamination by human and animal wastes, which can contain a variety of bacteria, viral and protozoan pathogens. The potential consequences of microbial contamination are such that its control must always be of paramount importance and must never be compromised. Microbial risk can never be entirely eliminated, because the diseases that are water borne may also be transmitted by person to person contact, aerosol and food intake. Waterborne outbreaks are particularly to be avoided because of their capacity to result in simultaneous infection of high proportion of the community.

The health risk due to toxic chemicals in drinking water is different from that caused by microbiological contaminants. There are few chemical constituents of water that can lead to acute health problems except

through massive accidental contamination of a supply, experience shows that in such incidents, the water becomes undrinkable for the unacceptable odor, taste and appearance.

In assessing the quality of drinking water, the consumer relies principally upon his sense and will evaluate the quality and acceptability of water on the basis of appearance, taste and odor of water. Many parameters must be taken into consideration in the assessment of water quality such as source protection, treatment efficiency and reliability and protection of the distribution network. The cost associated with water quality surveillance and control must also be carefully evaluated before developing national standards that can be readily implemented and enforced. For example the adoption of drinking water standards that are too stringent could limit the availability of water supplies that meet those standards. It is a significant consideration in regions of water shortage; however, considerations of policy and convenience must never be allowed to endanger public health. The final judgment as to whether the benefit resulting from the adoption of any of the guide line values taken as standards justifies the cost is for each country to decide (WHO 1993).

Guide lines values have been set for potentially hazardous water constituents and provide a basis for drinking water quality, their nature is such that:

- a. A guide line value represents the concentration of a constituent that does not result in any significant risk to the health of the consumer.
- b. The defined quality of water is such that it is suitable for human consumption and for all usual domestic purposes.



- c. When a guide line value is exceeded, it is a signal to investigate the cause and to consult the authority responsible for public health for his advice.
- d. A guide line value should not be regarded as the drinking water quality may be degraded to the recommended level, efforts should be made to maintain the highest possible level.

**Table (2.3)****WHO drinking water quality standards.**

Properties	Parameters	Units	Standards	
			Maximum Acceptable Concentration	Maximum Allowable Concentration
Physical	Color	Pt-Co	5	15
	Taste	-	non objectionable	Non objectionable
	Odor	-	Non objectionable	Non objectionable
	Turbidity	SSU	5	20
	pH	-	6.5-8.5	9.2
Chemical	Total Solids	mg/dm <sup>3</sup>	500	1.500
	Iron (Fe)	mg/dm <sup>3</sup>	0.5	1.0
	Manganese (Mn)	mg/dm <sup>3</sup>	0.3	0.5
	Fe & Mn	mg/dm <sup>3</sup>	0.5	1.0
	Copper (cu)	mg/dm <sup>3</sup>	1.0	1.5
	Zinc (Zn)	mg/dm <sup>3</sup>	5.0	15.0
	Calcium (Ca)	mg/dm <sup>3</sup>	75 <sup>b</sup>	200
	Magnesium (Mg)	mg/dm <sup>3</sup>	50	150
	Sulphate (SO <sub>4</sub> )	mg/dm <sup>3</sup>	200	250 <sup>c</sup>
	Chloride (Cl)	mg/dm <sup>3</sup>	250	600
	Fluroride (F)	mg/dm <sup>3</sup>	0.7	1.0
	Nitrate (NO <sub>3</sub> )	mg/dm <sup>3</sup>	45	45
	Alkylbenzyl Sulfonates (ABS)	mg/dm <sup>3</sup>	0.5	1.0
	Phenolic substance (as phenol)	mg/dm <sup>3</sup>	0.5	1.0
Toxic elements	Mercury (Hg)	mg/dm <sup>3</sup>	0.002	-
	Lead (Pb)	mg/dm <sup>3</sup>	0.05	-
	Arsenic (As)	mg/dm <sup>3</sup>	0.05	-
	Selenium (Se)	mg/dm <sup>3</sup>	0.05	-
	Chromium (Cr hexavalent)	mg/dm <sup>3</sup>	0.05	-
	Cyanide (CN)	mg/dm <sup>3</sup>	0.2	-
	Cadmium (Cd)	mg/dm <sup>3</sup>	0.01	-
	Barium (Ba)	mg/dm <sup>3</sup>	1.0	-
Bacterial	Standard plate count	Colonies/cm <sup>3</sup>	500	-
	Total coliform	MPN/100cm <sup>3</sup>	2.2	-
	E.Coli	MPN/100cm <sup>3</sup>	None	-

**Remarks:**

Pt-Co Platinum Cobalt Scale

SSU Silica Scale Unit

Mg/dm<sup>3</sup> milligram per cubic decimeter

MPN Most Probable Number

- a. These values are allowed for tap water or ground water that is used as temporary drinking water. Such water with a parameter between the maximum acceptable concentration and the maximum allowable concentration can not be certified as standard drinking water for industrial products and stamped with the standard logo.
- b. If the calcium concentration is higher than the standard and magnesium concentration is lower than the standard, calcium and magnesium will be identified in terms of total hardness with a standard value of less than 300 mg/dm<sup>3</sup> (as CaCO<sub>3</sub>).
- c. If a sulphate concentration of 250 mg/dm<sup>3</sup> is reached, magnesium concentration must not be more than 30 mg/dm<sup>3</sup>.

***Source:***

**<http://www.pcd.go.th/Information/Regulations/WaterQuality/DrinkingWater.htm>**

**Table (2.4)**  
***Sudanese Drinking water Quality standards***

<b><i>Physical parameter</i></b>	<b><i>Levels likely to Give Rise to consumer complains</i></b>
Colour	15 TCU
Taste and Odour	Acceptable
Temperature	Acceptable
Turbidity	5 NTU
PH	6.5 – 8.5
<b><i>Inorganic Constituents</i></b>	
Aluminum	0.2 mg/L
Ammonia	1.5 mg/L
Chloride	250 mg/L
Hydrogen sulfide	0.05 mg/L
Iron (total)	0.3 mg/L
Sodium	200 mg/L
Sulfate	250 mg/L
Total Dissolved Solids (TDS)	1000 mg/L
Zinc	3 mg/L
<b><i>Organic Constituents</i></b>	
2-Chlorophenol	5µg/L
2,4 Dichlorophenol	2µg/L

**Con. Table (2.4)**

<i>Toxic elements</i>	<i>Max permissible limit in mg/L</i>
Antimony	0.004
Arsenic	0.007
Barium	0.5
Boron	0.2
Cadmium	0.003
Chromium (total)	0.04
Copper	1.5
Cyanide	0.05
Fluoride	1.5
Lead	0.007
Manganese	0.007
Mercury (Total)	0.0007
Molybdenum	0.05
Nickel	0.014
Nitrate as No3	50
Nitrate as No2	2
Selenium	0.007

**Cont. Table (2.4)**

<i>Organisms</i>	<i>Guideline value</i>
1} All water intended for drinking A/ E.coli or thermotolerant coliform bacteria B/ Pathogenic intestinal protozoa	Must not be detectable in any 100-ml sample
2} Treated water entering the distribution system A/ E.coli or thermotolerant coliform bacteria B/ Total coliform bacteria. C/ Pathogenic intestinal protozoa	Must not be detectable in any 100-ml sample
3} Treated water in the distribution system A/ E.coli or thermotolerant coliform bacteria B/ Total coliform  C/ pathogenic intestinal protozoa	Must not be detectable in any 100-ml sample. Must not be detectable in any 100-ml sample. In the case of large supplies where sufficient samples are examined, must not be detectable in 95% of samples examined through any consecutive 12-months period Must not be detectable in any 100-ml sample.

***Source: Khartoum State Water Corporation***

## ***2.5 Water Resources in North Darfur:***

The resources of water in North Darfur State are itemized as follows:

1. Surface water resources.
2. Groundwater resources.

### ***2.5.1 Surface water resources:***

The availability of surface water resources is governed by rainfall and surface runoff.

#### ***2.5.1.1 Rainfall:***

The average annual precipitation in North Darfur State ranges from zero in the north to some 600 mm in the south, the long term total precipitation over the entire region averages some 300mm/annum. The rainy season in the state extends from June to September every year. In the area between Lat 12<sup>0</sup> and 15<sup>0</sup> N, 85% of the total rain falls between July and September, July and August are the most rainy months, during which about 60% of the total precipitation falls. Most of the rains fall in the form of heavy thunder-storms of short duration.

The variability in the average annual rainfall in the state ranges from 20% at the south and south west (Jebel Marra) to more than 95% at the extreme north. For the last 30 years the Sahel area of the region has been inflicted by drought and the amount of annual rainfall has dropped to 70% of the long term mean. The variability in time and place of the amount of annual rainfall increased the risk of crop cultivation which pushed the farmers to cultivate more land in order to secure the same crop output. Such practice in the ecologically fragile areas has successively impaired land productivity, increased soil erosion and induced desertification. Drought and desertification which swept the whole

country have forced a large sector of the population of North Darfur to leave to the more humid areas of southern Darfur and Jebel Marra.

In general North Darfur suffers from an acute deficit in its annual water budget. The greatest part (north of Lat 12<sup>0</sup>N) has 11 to 12 arid months, the southern areas have 8 to 9 arid months while the remaining 3 to 4 months have a variable water surplus. In most areas with a total annual precipitation exceeding 300 mm, July and August show water surplus. This surplus either infiltrates through the top soil or recharges the shallow aquifers or flow over the ground surface as runoff. (Baseline Survey of Darfur Region 1988)

#### **2.5.1.2 Surface Runoff:**

The water surplus in the region is mostly reflected as seasonal Wadis, Khors and Rahads. Small portion of this surplus water is gathered and conserved either behind small dams or in artificially excavated ponds locally known as Hafirs. Most of the streams in North Darfur region are usually running during and shortly after the rainy season. No flow record available for most of these streams, and hence fairly accurate appraisal of surface water potential over the entire region of Darfur is a guess work.

The long term real rainfall runoff coefficient over the entire area of Darfur region is estimated as 1.5% (UNFAO)

##### **a) Wadi Kutum:**

Wadi Kutum has an active catchment's area of 3500 sq. km., mostly of exposed basement complex rocks at the north eastern piedmont of Jebel Marra. Average rainfall over the basin area is about 350 mm/annum. The rainfall runoff coefficient is



estimated as 2% which corresponds to a total surface flow of 25 Mm<sup>3</sup> of water every year.

b) **Wadi El Ku System:**

Wadi El Ku and its tributaries drain from the eastern slopes of Jebel Marra. The Wadi after leaving the piedmont zone turns southwards crossing Sag El Naam clayey plain and continues till it ends in a silty delta at Muhageria east of Nyala Town.

The catchment's area of the Wadi is about 25,000 sq.km with an average rainfall of 300 mm every year. The major parts of the catchment's area are extremely flat, and are underlain by the pervious Nubian Sandstone formation. Accordingly, the rainfall/runoff coefficient over the entire basin is expected to be low not exceeding 1.5%, this corresponds to a total surface flow of 100Mm<sup>3</sup> of water every year.

The flow of the major tributaries of Wadi El Ku is either obstructed by a series of dams e.g. Golo Dam (cap. 2.5Mm<sup>3</sup>) and Abu Zuraiga (cap. 1Mm<sup>3</sup>) or diverted to fill some 30 Hafirs of a total capacity 1 Mm<sup>3</sup> of water.

***2.5.2 Groundwater Resources:***

Groundwater is the only permanent source of water in the entire region of Darfur. The main water bearing formations in the state are:

1. Alluvial Aquifers.
2. Nubian Sandstone Aquifer.

Such itemization is based on the ability of the formation to absorb and transmit groundwater in appreciable quantities. However the Tertiary volcanic of J. Marra Massive which are considered as a non water bearing, store tremendous volumes of rain-water every year within their

intensive hexagonal joints., and keep feeding the perennial streams radiating from the Jebel with water for good part of the year.

#### ***2.5.2.1 Alluvial Aquifers:***

The alluvial aquifers underlie most of the seasonal streams, especially those radiating from Jebel Marra. They are mainly composed of the course valley fill deposits which occur at the Wadi bed and along its banks. These aquifers are the source of considerable amounts of good quality groundwater which is currently utilized for domestic use as well as for supplementary irrigation in Kutum and Kebkabia regions.

Groundwater in the alluvial aquifers generally occurs under free water table conditions and at shallow depths hardly exceeding 10m below the ground surface.

Alluvial aquifers in Kutum and kebkabia regions are fully recharged every year, principally through influent seepage from the seasonal floods. And to a lesser extent from direct precipitation. The water table attains its highest levels during and shortly after the rainy season and recedes progressively till the beginning of the next rains. In dry seasons, or where the water bearing sediments are there in, the water table near the end of the dry season drops below the base line of the aquifer, and the wells either dry up or produce small amounts of water from the underlying weathered basement surface.

Groundwater tapped from the alluvial aquifers in Darfur region is known to be fresh with low content of dissolved mineral salts rarely exceeding 300 ppm. The waters are suitable for domestic use and have a Sodium

Absorption Ratio (SAR) ranging from 0 to 10: they are good waters for irrigation (base line survey for Darfur Region 1988).

**\* Wadi Kutum Alluvial Aquifer:**

The alluvial aquifer underlying wadi Kutum extends over an area 100km. long east and west of Kutum Town. The aquifer has a mean width of 200m and an average thickness of approximately 10m depth to water table varies from few cms. Following recharge from the Wadi floods to 5m below the ground surface near the end of the dry season.

The alluvium of Wadi Kutum is mostly well sorted, medium to coarse grained sand. With estimated permeability of 14m/d and specific yield of 20%. The water tapped from the aquifer is extensively used for supplementary irrigation of small plots grown with vegetables and fruits.

***2.5.2.2 Nubian Sandstone Aquifer:***

The Nubian Sandstone Aquifer is the most extensive and reliable aquifer in Darfur region. It underlies 260000 sq. km with thickness ranging from few meters to over 1000m. The aquifer is mainly comprised of interbedded well stratified sandstone, mudstone and conglomerates. The sandstones are homogeneous, mostly of medium to coarse grain size, which indicate uniform as well as extensive areas of deposition.

The Nubian Sandstone Aquifer fills several structural basins namely:

- i. Sahara Basin
- ii. Umm Keddada Basin
- iii. Wadi El Ku Trough
- iv. Disa Outlier (in West Darfur)

### 1) **Sahara Basin:**

The Sahara Basin covers an area of 200.000 sq. km extending to the northern parts of West Darfur and North Kordofan States. The basin is limited from south by the Nile Bahr El Arab Flat water divide and extends north wards till it joins the Kufra Basin in Libya. It is further subdivided into several, mostly interconnected sub basins, namely:

- Wadi Howar and Tima (Mahaliat Kutum).
- Saniya Haiyeh (Mahaliat Mellit).

At the intake area of the aquifer close to the water divide, groundwater in the Sahara Basin mostly occurs under free water table. Such conditions change to semi-confined at the centre of the basin further to the north. The depth to water ranges from 3m to 45m below the ground surface. Groundwater sometimes crops out in the form of springs such as Ain Faro and Ain Saro north of Kutum Town, or is found close to the ground surface in areas along Darb El Arbaein such as Bir Atroon and Nekheila. Seasonal fluctuations in the water table are minimal and in spite of the drought which inflicted the region for the last 30 years, the regional groundwater level in the basin remained practically the same.

The groundwater in storage within the top 100m of the Nubian Aquifer in the Sahara Basin is estimated as  $200 \times 10^9 \text{ m}^3$ . The main recharge to the basin is from surface runoff at the intake area which is conservatively estimated as  $50 \text{ Mm}^3$  of water every year. The present abstraction of groundwater does not exceed  $1 \text{ Mm}^3$ , which indicates that the aquifer is still virgin and mostly untapped.

The quality of the groundwater in the Sahara Basin is extremely fresh with salinities ranging from 60ppm at the intake area, to 400ppm further to the north; it is suitable for human and animal consumption as well as for irrigation.

## **2) Umm Keddada Basin:**

Umm Keddada Basin covers 55000 sq. km south of the Nile-Bahr El Arab water divide. It occupies most of the central and eastern parts of Darfur and extends further to the east to adjoin Wad Banda, Sug El Gamal and Rigl El Fula Sub-Basins in Western Kordofan State. On the west Umm Keddada Basin is connected through the strait of Saniya Karaw to the deep trough of Wadi El Ku. Further to the south the basin is hydraulically connected to the large Baggara Basin through Umm Gafala Gap.

The thickness of the Nubian Aquifer filling Umm Keddada Basin is highly variable, ranging from a few meters to some 250m. The depth to water at intake area where free water table conditions prevail is shallow, ranging from 20 to 50m below the ground surface. As the thickness of the Nubian Sandstone Aquifer increases, confined conditions start to appear and the depth to the groundwater reaches 150m below the ground surface.

Groundwater flow within the Nubian Aquifer in Umm Keddada Basin is mostly from the water divide to the south and the groundwater gradient gradually decreases from 1:250 south of the Meidob to 1:550 at Umm Keddada and then increases to 1:400 at Umm Gafala Gap. These variations in gradient are largely due to the configuration of the underlying Basement Complex, and to the variability in the thickness of the aquifer.

The salinity of the groundwater gradually increases as the water moves from the recharge areas near the water divide (70ppm) to

the centre of the basin (2500ppm). The mean value of the salinity all over the basin is 400ppm. Local pockets of exceptionally high salinities occur around Jebel Hilla (EC 3600) and Umm Shanga (EC 20000). With the exception of these high saline pockets, the ground water tapped from the Nubian Aquifer of Umm Keddada Basin is now used for domestic purposes and for drinking of livestock. Similarly most of these waters are tentatively suitable for irrigation purposes especially on the coarse textured soil dominating central and eastern parts of North Darfur State (Burush village).

### **3) Wadi El Ku Trough:**

Wadi El Ku Trough is a NW-SE faulted block west and south-west of El Fasher. The trough is some 120 km long and 30km average width. It is subdivided by a basement ridge into two basins, Shagera and Sag El Naam Basins. The two basins are hydraulically interconnected through the alluvial aquifer of Wadi El Ku and through the joints and fissures of the basement ridge separating them.

Shagera Basin is a Nubian outlier of an area 1250 sq.km west of El fasher Town. The Aquifer is a medium to coarse grained sand stone, often intruded by Tertiary basaltic silts. The thickness of the aquifer is about 500m. Groundwater in the Nubian Aquifer of Shagera basin mainly occurs under free water table to semi-confined conditions, at depths ranging between 40 to 60m below the ground surface. The regional flow of the groundwater is from the basement in a southeasterly direction into Sag El Naam Basin with a hydraulic gradient of about 1:600. Annual recharge to the aquifer is to a great extent from the spatial flow of Wadi El Ku and

its tributaries. The groundwater of Shagera Basin is generally tapped for the domestic water supply of El Fasher Town, the capital of the state.

Sag El Naam is a rectangular NW-SE trough, some 75km long and 30km average width. The thickness of the aquifer varies from 300m at the fringes to over 2000m at the centre of the basin. Groundwater in the Nubian Sandstone Aquifer of Sag El Naam Basin occurs under free water table conditions at depths ranging from 30 to 90m below the ground surface. The general movement of groundwater is from northwest to southeast, then to the east through the gap of saniya Karau to Umm Keddada Basin.

The Nubian Aquifer in Sag El Naam Basin is composed of a series of coarse and sometimes gritty weakly cemented sandstone interbedded with streaks and sometimes thin beds of mudstone. The groundwater tapped from the Nubian Aquifer of Sag El Naam Basin is normally fresh, suitable for domestic and irrigation purposes. The basin is gaining considerable amount of fresh water recharge from the tributaries which join Wadi El Ku within the area of Sag El Naam.

## ***2.6 Water Supply Systems in North Darfur:***

Since 70% of the North Darfur people are rural settlers and nomads, it is important to provide water for them from reliable sources and in a sustainable manner in order to improve their socio-economic conditions. Provision of water from sustainable sources controls the pattern of life and remains to be the most acute problem and became a first priority of the rural communities and the decision makers of the state. (Hydromaster Inc. 1998).

There are five water supply systems in North Darfur State:

- 1- Traditional.
- 2- Hafirs and Dams
- 3- Hand dug wells.
- 4- Slim boreholes fitted with pumps.
- 5- Water yards.

#### ***2.6.1 Traditional Systems:***

It includes natural water pools, depressions and water channels which seasonally pond rainwater for both human and livestock needs. The system also includes traditional open wells which dug through the beds of wadis and flood plains.

These waters usually last up to two months after the last rainfall or runoff. They are liable to contamination and silting by the seasonal floods.

#### ***2.6.2 Hafirs and Dams:***

These are man-made depressions to harvest surface runoff. It is an important source of water supply particularly at places underlain by rocks of the basement complex, they are constructed where no groundwater resources are available, soil conditions are favorable and surface runoff is adequate.

Design capacities range from 10.000 up to 60.000m<sup>3</sup> for Hafirs and from 250.000 up to 2Mm<sup>3</sup> for Dams. Due to losses from evaporation, seepage and annual silting, Hafirs and Dams retain only about 50-60% of the design capacity as water for use, which is not clean and susceptible to



contamination since they lack any physical or chemical treatment facilities, unfenced and animals are not separated from human.

There are about 45 Hafirs and 28 Dams in North Darfur scattered all over the State according to the table below:

**Table (2.5)**  
***Hafirs & Dams in North Darfur***

<b>Mahaliah</b>	<b>Admin. Unit</b>	<b>Hafirs</b>	<b>Dams</b>
El fasher	El fasher – Elkooma	11	6
	Dar Assalam	10	2
	Taweela – Corma	3	1
Kutum	Kutum – Fatta Barno	2	2
El Teina	Karnoy – Am Barow	4	9
Kabkabia	Jebel Cei	-	2
	Saraf Omra	11	2
Mellit	El Sayah	2	2
	El Malha	-	2
Umm Kaddada	El Tiwasha	2	-
Total		45	28

(Information is given by SDWC)

### ***2.6.3 Hand dug Wells:***

They are usually constructed in basement complex and/or alluvium formations to a depth of 15-50m and 1.5m diameter, with a yield of 2.5m<sup>3</sup>/h to meet the water demand of small rural communities. Hand dug wells are lined with cement blocks from the upper parts down to the

stable formation. They are simple and require minimum maintenance, however if not properly designed and maintained, they are liable to pollution. There are more than 500 hand dug well in the state.

#### ***2.6.4 Slim Boreholes fitted with pumps:***

The system is known as handpumps, it has been introduced in North Darfur State in 1992 by the UNICEF/NWC (Water, Environment and Sanitation – WES project). The handpump system is composed of a 4 in dia. borehole, a hand pump and a platform to extract groundwater from fractured / weathered basement rocks at depth not exceeding 70m. The standard borehole is designed to serve about 200 persons with a minimum, production rate of 1m<sup>3</sup>/h of potable water according to WHO standards.

At present there are more than 1200 hand pumps in North Darfur State supplying about 1Mm<sup>3</sup> per year of potable water and with operation and maintenance responsibilities carried out by the rural committees.

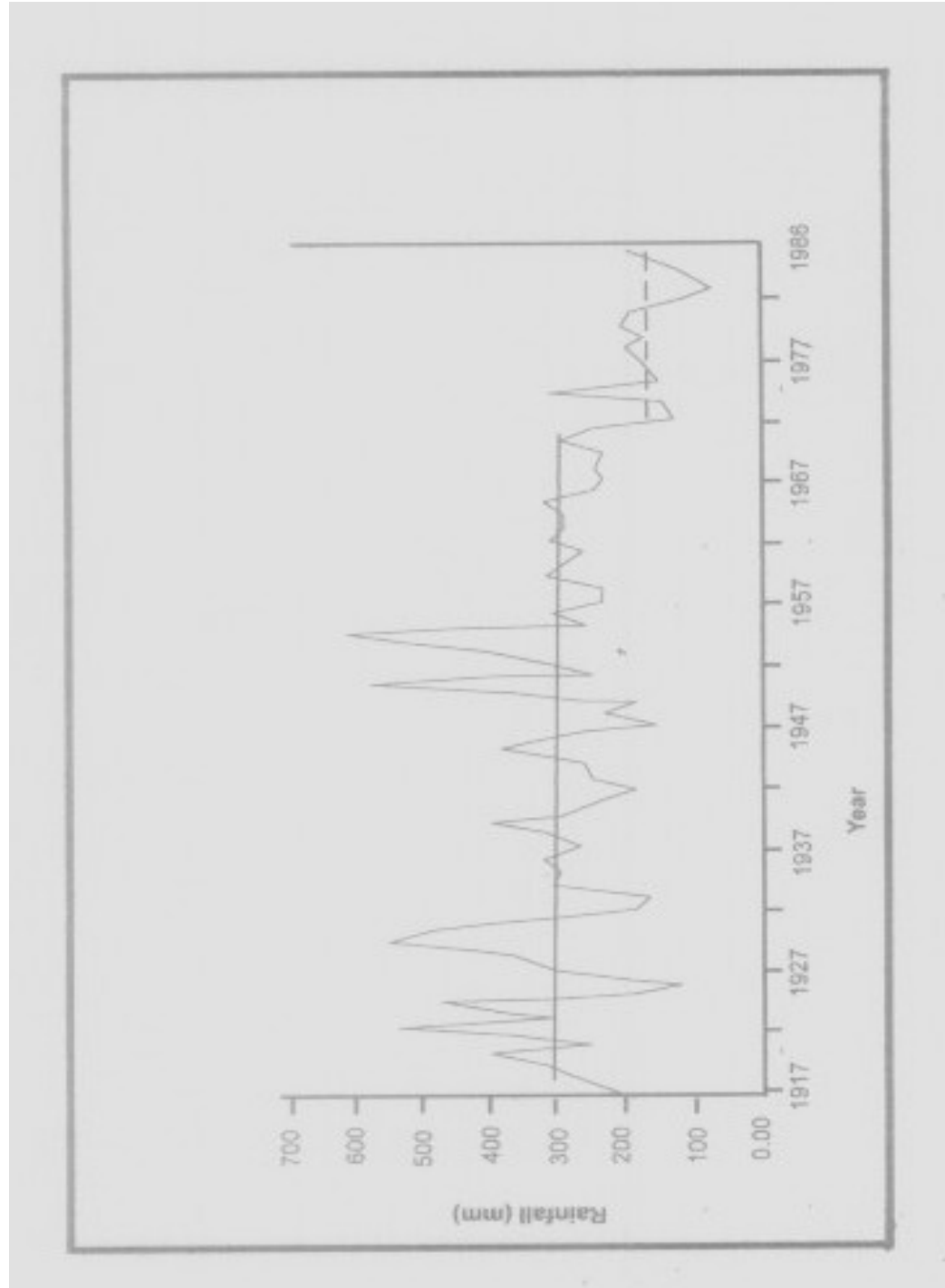
#### ***2.6.5 Wateryards:***

The term wateryard is applied to a water extraction system and distribution complex which includes one or more boreholes (100 – 300m deep) fitted with pumps driven by diesel engines, elevated storage tank from which water is delivered to tap stands, animal troughs and human filling benches. A wateryard may be enclosed within a rectangular fence compound 60\*80m. Average water yield of a waeryard in North Darfur varies between 3 -20m<sup>3</sup>/h of which more than 40% goes to livestock consumption. The boreholes tap permanent deep groundwater aquifers.

Due to the current drought events, wateryards are the only source of water that can rely upon and despite the relatively complicated system, it remains almost the only option in some places in the state (e.g. Mahaliat Umm Keddada).

Presently there are about 143 wateryards with a total of about 276 boreholes, with various types of pumps and engines. They operate under great and excessive pressure made by the bulk of water demand for people and livestock especially during dry months, which involve close supervision to keep them operating.

**Fig. (2.2)**  
***Rainfall in El Fasher area***



## ***2.7 Water Resources for Elfasher Town:***

The available resources for the town water supply are:

1. Surface water resources.
2. Ground water resources at Shagera and Sag El Naam basins.

### ***2.7.1 Surface water resources:***

The mean of the annual rainfall for the last 5 decades was 287 mm/year and since early 1970s there has been a continuous general downward trend below the long term mean, this was recorded as 190mm. The occurrence of rainfall is during June to October, creating a seasonal runoff coming through many wadis north and west of El fasher replenishing Golo reservoir and the two Hafirs, and continuing to the southwest of El fasher through Khor Golo, Khor Shagera and with other wadis making Wadi El Ku and continue to Sag El Naam area. The only gauging station on Wadi El Ku is at Sag El Naam area, and is established in 1977. Table (2.6) shows records of this gauging station (Ministry of Irrigation).

***Table (2.6)***  
***Records of Wadi El Ku Gauging Station***

<b>Season</b>	<b>Obs. Period</b>	<b>No. floods</b>	<b>Max. disch. M<sup>3</sup>/s</b>	<b>Ann. Disch m<sup>3</sup></b>
1977	22.8 – 30.8	1	26.01	5060204
1978	16.8 – 9.9	5	18.75	1457860
1979	4.8 – 1.9	7	54.92	4375031
1980	16.7 – 27.8	8	124.11	16951910
1981	10.7 – 27.8	6	18.74	2704500
1982	18.8 – 31.8	7	17.61	16466820
1983	2.8 – 3.9	4	15.79	2908924
1984	No data	0	-	-
1985	No data	0	-	-
1986	24.7 – 24.9	5	6.27	3179664
1995	21.7 – 17.9	7	5.9	1944180

Golo reservoir and the two Hafirs were constructed on clay soil, so a considerable quantity of surface water should be stored during the rainy season every year. There is a quantity of yearly storage capacity of  $2.5\text{Mm}^3$  from the available runoff.

### ***2.7.2 Groundwater resources:***

The first systematic work on the water resources of the area was carried out by Hunting Mac Donald during their investigation in the Darfur Province between 1968 and 1970, during this period they undertook geophysical and hydro geological surveys which led to the delineation of the main groundwater basins of Sag El Naam, Shagera and Umm Keddada. The first two basins were available groundwater resources for El fasher town.

#### ***2.7.2.1 The Shagera Basin:***

- 1- In 1975 Mohamed A. M. described in details the hydrogeology of Shagera basin and made recommendations for its exploitation. In 2002 Hydromaster Inc. has conducted a geoelectric study for the Shagera basin covering an area of 867 sq. km and confirmed that groundwater in the basin occurs in the Nubian Sandstone and is stored under both confined and unconfined conditions, average of 50m below the ground level. From the study it appears that the unconfined part comprises some 483 sq. km and the confined part is 117sq.km, and the volumes of the unconfined and the confined sections of the aquifer are estimated to be  $12394\text{ Mm}^3$  and  $10800\text{ Mm}^3$ .
2. Aquifer Properties: During 1969 and 1972, pumping tests were undertaken in nine boreholes in the Shagera well field. Four of the

test observation wells data were used to determine the hydraulic properties of the aquifer. A summary is listed in table (3). Table (4) summaries the values of the hydraulic parameters of the shagera well field.

Average transmissivity T is approximately  $180 \text{ m}^2/\text{d}$

Average permeability K is approximately  $1.18 \text{ m/d}$ .

The variation in transmissivity was due to the thickness of the aquifer and permeability, while the variation in permeability appears to be linked with the degree of fissuring of the aquifer – this being indicated by zones of loss of circulation during the drilling of the boreholes. The transmissivity of the sandstone progressively decreases west of the Shagera well field as a result of thinning of the aquifer; in this direction storage coefficients obtained from the tests are of order of  $10^{-4}$  indicating confined conditions which was provided by the volcanic overburden that has significantly lower permeability than that of the aquifer.(Howard Humphreys, Elfasher W.S. Final Report)

**Table (2.7)**  
**List of Pumping Tests result in Shagera Well Field**

<b>Pumped borehole s</b>	<b>Observation wells</b>	<b>Discharge (L/S)</b>	<b>Drawdown (m)</b>	<b>Duration (minutes)</b>	<b>Remarks</b>
3071	-	6.69	11.3	100	1970
3071	4877 / 4878	2.42 5.68 8.18	3.50 9.82 14.84	4405 4320 7200	1972
3767	3072 3772	6.83	10.91	4215	1970
3767	3768 3771 3772	2.5 5.3 8.81	3.58 8.63 16.27	4320 4505 5805	1972
3769	-	6.17	34.6	100	1970
3771	-	1.14 2.27	44.59 49.70	60 80	1971
3772	-	1.51 4.55	6.12 9.50	150 690	1971
3773	-	2.27 4.55	12.34 24.36	160 460	1971
4878	-	1.51 2.27 4.55	1.55 3.50 4.77	150 375 735	1971
5631	5632	2.72 5.07 8.18	2.73 1.085 3.34	4320 4320 4320	1972

**Source: Howard Humphreys and Partners 1983**  
**Elfasher Water Supply**  
**Final Report**



***Tale (2.8)***

***Shagera Well Field: Summary of Hydraulic Parameters***

<b>Borehole No</b>	<b>T (m<sup>2</sup>/d)</b>	<b>K (m/d)</b>	<b>S (dimensionless)</b>	<b>K (m/d)</b>
4878	76	0.44	$1.02 \times 10^{-4}$	0.0064
4877	84	0.75	$1.90 \times 10^{-4}$	0.0063
3768	285	2.1	$1.33 \times 10^{-4}$	-
3771	155	0.95	$1.69 \times 10^{-4}$	-
3772	177	0.80	$0.79 \times 10^{-4}$	-
3072	155	1.19	$1.56 \times 10^{-4}$	-
5632	345	2.05	$3.55 \times 10^{-4}$	0.0079

**3- Water Level Fluctuations and Groundwater recharge:**

Since 1972 up to present there have been no water level measurements in the Shagera Basin, except those carried out by Howard Humphreys in May 1981, shown in table (5) with other available records. The records do not indicate any trend of either falling or rising water levels. The long term situation appears to be one of stable water levels which indicate that the aquifer receives annual replenishment.

The groundwater recharge to the sandstone is derived from:

- 1- Direct infiltration of rainfall.
- 2- Infiltration of runoff during periods of floods in the wadis
- 3- Horizontal leakage of groundwater stored in the weathered basement aquifer and wadi fill.
- 4- Vertical downward leakage from the overlying volcanic.

The replenishment nature of the sandstone in the Shagera basin is demonstrated by:

- a. The response of water levels to rainfall
- b. The groundwater is in motion
- c. The hydraulic continuity between the sandstone and the shallow phreatic aquifers.
- d. The existence of phreatic conditions at the outcrop in areas where the volcanic cover is relatively thin.
- e. The variation in groundwater chemistry.

Hunting (1970) made studies in Wadi Kutum and estimated that the infiltration to the alluvial aquifer in this wadi represents approximately 1.3% of the rainfall over the impermeable catchments. On this basis the recharge to the Shagera Basin can be estimated to be 2.19 Mm<sup>3</sup>/annum

Average rainfall 1970 – 1980	: 194 mm
Proportion infiltrating	: 2.52 mm
Area of Shagera Basin	: 867 sq.km
Quantity of recharge	: 2.19 Mm <sup>3</sup>

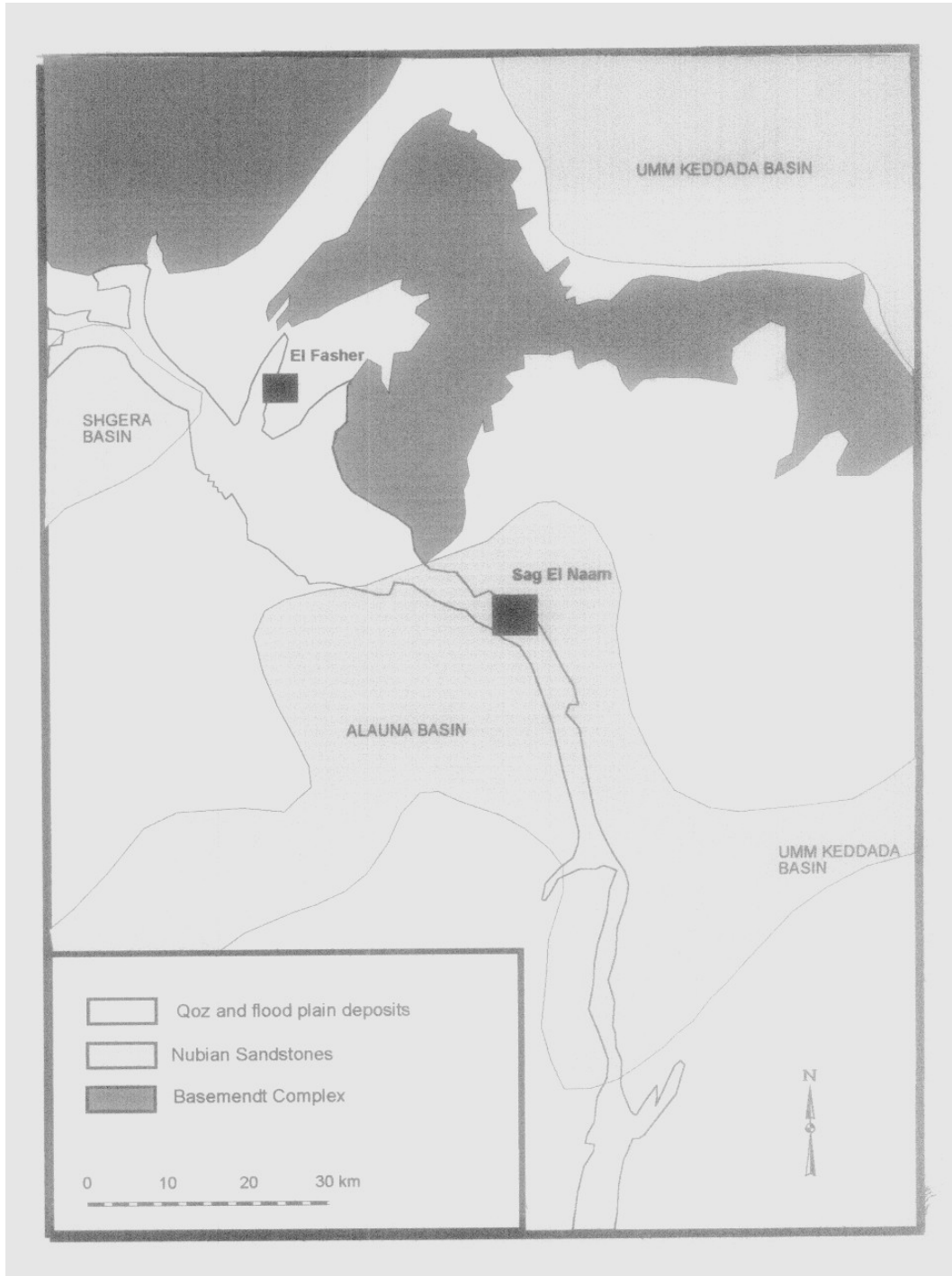
However, based on Darcy equation (groundwater flow through soil), the annual safe yield of the aquifer was tentatively estimated to be 2Mm<sup>3</sup>/year of which 80% can be abstracted from boreholes.

**Table (2.9)**  
**Water Level Fluctuations in Shagera Well Field**  
**(1969 – 1981) Meters below ground level**

Borehole No	1969	1970	1971	1972	1981
3071	44.5	-	-	-	40.43
3072	44.6	45.1	-	-	47.70
3768	-	45.1	45.7	45.7	45.41
3769	-	46.5	45.7	44.8	-
3772	-	44.5	45.41	44.8	46.08
4877	-	-	45.70	46.32	47.06
5420	-	-	46.38	46.32	44.46

**Fig. (2.3)**

***Location of Shagera and Sage El Naam Basins***



### ***2.7.2.2 The Sag El Naam Groundwater Basin:***

#### **1. Introduction:**

Water development from Sag El Naam Basin is undertaken mainly by the State Drinking Water Corporation (SDWC) through 18 water yards distributed throughout the basin area to meet the drinking demand of the rural areas; each water yard contains one to three boreholes, total number of 30 wells with total annual abstraction  $1.6 \text{ Mm}^3$ . In the seventies, 32 wells were drilled for the Sag El Naam Agricultural Project which is not working now due to cut-off of operation and subsidy from the central government. Latest feasibility study of this project recommended the use of the groundwater resources for supplementary irrigation of crops based on flood water spreading. The groundwater resource of Sag El Naam is considered a safe source, quality and quantity and the SDWC is currently planning to supply El fasher Town from the basin on the long term.

#### **2. Groundwater Occurrence:**

The gravelly sandstone layers of the Nubian Sandstone Formation are the main water bearing formations within the basin. They consist of coarse, gravelly sub angular to well rounded sand grains, layers are generally poorly cemented and compacted. The basin is surrounded from north, west and south by the basement complex rocks; it is open to the east, where it is hydraulically connected to Umm Keddada Basin via Saniya Karaw-Umm Beitien gate. The basin surface area is about 2700 sq. km and average thickness between 200 to 300m. Groundwater in Sag El Naam occurs under free water table conditions. The average depth to water table throughout the basin is 70-80m below the ground surface.

Past records of water level monitoring (Hunting 1970) showed that the groundwater table slopes west of the basin are higher than those in the east near Saniya Karaw indicating a southeasterly trend of groundwater movement to Umm Keddada Basin through Saniya Karaw-Umm Beitien gate.

### **3. Aquifer Hydraulic Parameters:**

In 1991 H.M.Kaskous through his Msc thesis about Sag El Naam Basin, has calculated the aquifer parameters using two methods, grain size analysis and pumping test. The grain size analysis results are presented in table (6). Eight pumping tests were conducted for a period of 1440 minutes for each test. Complete recovery test data were recorded for almost all the tested wells. Four methods adopted for the evaluation of the pumping test data, they were:

- I. Theis' s Method.
- II. Chow' s Method.
- III. Jacob's Method.
- IV. Theis's Recovery Method.

Results are presented in table (2.10).

**Table (2.10)**  
***Hydraulic parameters from grain size-analysis***

<b>Locality</b>	<b>Well No.</b>	<b>Sample No.</b>	<b>Km/s</b>	<b>N</b>	<b>n<sub>o</sub></b>
Sag El Naam	5634	1	$7.8 \times 10^{-4}$	0.275	0.261
		2	$7.8 \times 10^{-4}$	0.280	0.260
		3	$5.3 \times 10^{-4}$	0.270	0.265
		4	$5.3 \times 10^{-4}$	0.275	0.261
		5	$8.0 \times 10^{-4}$	0.290	0.271
		6	$8.0 \times 10^{-4}$		
Sag El Naam	4394	1	$1.6 \times 10^{-4}$	0.270	0.238
		2	$8.8 \times 10^{-4}$	0.265	0.248
		3	$6.7 \times 10^{-4}$	0.285	0.262
Abu Deleiq	10562	1	$7.0 \times 10^{-4}$	0.300	0.279
		2	$9.0 \times 10^{-4}$	0.29	0.270
		3	$9.0 \times 10^{-4}$	0.27	0.251
		4	$8.0 \times 10^{-4}$	0.27	0.254
		6	$8.0 \times 10^{-4}$	0.30	0.276
		7	$8.0 \times 10^{-4}$	0.305	0.285
Saniya Karaw	10564	2	$5.0 \times 10^{-4}$	0.350	0.323
		3	$5.0 \times 10^{-4}$	0.259	0.273
		4	$3.0 \times 10^{-4}$	0.315	0.290
		5	$7.0 \times 10^{-4}$	0.290	0.276
Idd El Baida	10563	1	$8.0 \times 10^{-4}$	0.30	0.282
		2	$9.0 \times 10^{-4}$	0.29	0.273
		3	$9.0 \times 10^{-4}$	0.31	0.282
		4	$8.0 \times 10^{-4}$	0.31	0.285
		5	$8.0 \times 10^{-4}$	0.315	0.299
Bahr Umm Durman	10567	1	$8.0 \times 10^{-4}$	0.300	0.27
		2	$8.0 \times 10^{-4}$	0.29	0.26
		3	$6.0 \times 10^{-4}$	0.27	0.25
		4	$8.0 \times 10^{-4}$	0.27	0.25
		5	$8.0 \times 10^{-4}$	0.28	0.26
		6	$6.0 \times 10^{-4}$	0.28	0.26

**Table (2.11)**  
**Hydraulic parameters from Pumping Test Analysis**

<i>Locality</i>	<i>Well No.</i>	<i>Theis method</i>		<i>Chow method</i>		<i>Jacob method</i>		<i>Recovery</i>
		<b>T</b>	<b>S</b>	<b>T</b>	<b>S</b>	<b>T</b>	<b>S</b>	<b>T</b>
Sag El Naam	6959	-	-	790	$1.5 \times 10^{-2}$	879	$1.3 \times 10^{-2}$	
Alauna	1687	-	-	920	-	920	-	666
Qereiwid Bashan	3033	-	-	744	-	744	-	
Abu Deleiq	10562	-	-	2082	-	2082	-	2034
Saniya Karaw	10564	-	-	1710	-	1710	-	724
Idd El Baida	10585	-	-	50	-	50	-	41
Idd El Baida	10563	-	-	56	-	56	-	41
Bahr Umm Durman	10567	-	-	18	-	18	-	20

**T = coefficient of transmissivity in m<sup>2</sup>/day.**

**S = storage coefficient, dimensionless**

Generally the basin is characterized by high transmissivity values ranging from 660 to 2080m<sup>2</sup>/day, with an average value of 1200m<sup>2</sup>/day, high value is attributed to the nature of the water bearing layers, being gravelly and loosely consolidated with high thickness.

#### **4. Water Resources:**

The groundwater system of Sag El Naam Basin is a steady state system since the phenomenon of recharge to and discharge from the aquifer do exist. The main source of recharge to the basin is the subsurface flow of groundwater from Shagera Basin and Shangil Toobaya area and is demonstrated by:

- Seasonal groundwater level fluctuations
- The existence of a significant hydraulic gradient.
- Generally low salinity values.

The groundwater discharge is mainly taking place as subsurface outflow through saniya Karaw-Umm Baitein gate to Umm Keddada Basin and as artificial discharge from the wells tapping the aquifer.

Based on Darcy equation, H.M.Kas. calculated the recharge from:

Shagera Basin to be	22.5 Mm <sup>3</sup> /year
Shangil Toobaya area	3.5 Mm <sup>3</sup> /year
Total	26 Mm <sup>3</sup> /year
Outflow, to Umm Keddada Basin	12 Mm <sup>3</sup> /year
Amount pumped for rural water supply	1.6 Mm <sup>3</sup> /year
Amount pumped for irrigation nowadays	0.4 Mm <sup>3</sup> /year
Total	14 Mm <sup>3</sup> /year

The annual amount of water taken into storage is about 12 Mm<sup>3</sup>/year and the groundwater quantity in storage is calculated to be 100 milliard m<sup>3</sup> (hunting 1970). The total present artificial discharge of groundwater is 2 Mm<sup>3</sup>/year. The foreseen future development of groundwater resources of Sag El Naam Basin shall cover the following:

1. El fasher Town drinking water supply.
2. supplementary irrigation for agricultural project at Sag El Naam

H.M.Kaskous (1991) has conducted chemical analysis for the groundwater tapped from Sag El Naam Basin and concluded that almost all samples display concentrations within the recommended WHO (1984) and Sudanese Ministry of Health (1983) standards. So it is considered very safe water source to meet the present and future demand of drinking and domestic water supply of El fasher Town as well as irrigation of the proposed agricultural project at Sag El Naam area.



### ***2.8 History of El Fasher Water Supply:***

Until early 1950s El fahser depends for most of its water supply on the Fula. Privately owned hand-dug wells are excavated around the Fula, and these are still in use for domestic supplies and watering livestock.

The development of water-yards system in the region dates back to 1930s, up to 1950s there are 18 water-yards in El fasher area (Howard Humphreys), each was supplied by one or more boreholes, which generally exploited the water stored in the weathered basement aquifer.

In early 1950s, the Golo Reservoir and Hafir No 1 were constructed at about 10km west of the town, with a 600mm dia. concrete gravity pipeline was laid from Golo to El fasher, where it terminated at a small pond, from which water was pumped to the site of the town water treatment station and from there a distribution system of galvanized mild steel pipes served the military and the area west of the Fula. In 1960 a treatment plant was constructed, comprised of primary and secondary sedimentation tanks, two rapid gravity filters each of 30m<sup>3</sup>/h, two underground reservoirs for treated water and an elevated steel tank. The tank stores water for filter backwashing and also provides a constant head in the distribution system, which was supplied by two diesel engine driven pumps in the filter house.

The treatment works has been expanded in stages by the addition of pairs of filters in 1968, 1980 and 1981, a third reservoir for the treated water, and a horizontal flow settling tank.

The distribution system dates back to 1960, during that time water was supplied from kiosks or directly from the drilled water-yards in the town. Since that date it has been extended and reinforced on piecemeal bases. In

1974 a 200mm dia. asbestos pipeline of 12 km circular length was introduced after which consumer connections are understood to be available.

Hafir No 2 was constructed in 1967, in 1970 a pumping station was built at Golo and a 200mm dia. Pumping main was laid from Golo to the site of the treatment works at El fasher, a second main of 300m dia. was constructed in 1978. In 1976 a group of boreholes at Shagera El wadi to the west of Golo was connected to Golo head-works by a 200 mm dia asbestos pipeline. In 1980 the embankment of Golo reservoir was raised 1.5m to increase its storage to compensate for the reduction due to accumulation of silts over years. Another transmission line was laid between Shagera El Wadi and Golo station in 1981, and a central thermal power was constructed near Golo to replace the three separate generating facilities at Golo head works.

In 1982 a No. of boreholes were drilled at Shagera El Goz to the southwest of Shagera El Wadi and a 300m dia pipeline between them was constructed. Submersible pumps have been erected at Shagera boreholes in 1990 to increase their productivity and a 350mm dia. asbestos pipeline was laid from Shagera El Goz to El fasher which is carrying more than 70% of the town water supply, since the reservoir needs rehabilitation works on yearly basis to ensure its filling by rain water.

In 1994, 3 kms. Of 200mm dia. asbestos pipeline was added to strengthen the distribution system directly from El fasher station to a point on the perpendicular to the old ring, it enables more than 80% of the central quarters to have their share which was known to be distributed on weekly basis.

**Table (2.12)**  
**Historical development**  
**of El fasher water supply works**  
 (Information given by SDWC)

<b>Year</b>	<b>Water Works</b>
1940	Construction of two water-yards in El fasher town
- 1950	<ul style="list-style-type: none"> <li>- Increase the number of drilled water yards to 16 in El fasher town.</li> <li>- Construction of Golo reservoir and Hafir No. 1</li> <li>- Construction of a 600mm dia. concrete gravity pipeline from Golo to Elfasher.</li> </ul>
1960	<ul style="list-style-type: none"> <li>- Construction of the treatment works of primary and secondary sedimentation tanks</li> <li>- 2 rapid gravity sand filters.</li> <li>- 2 ground level treated water storage reservoirs and an elevated steel tank</li> </ul>
1960	- construction of Kiosks for water supply
1967	- construction of Hafir No. 2 at Golo
1968	- addition of pair of filters
1970	<ul style="list-style-type: none"> <li>- construction of pumping station at Golo</li> <li>- construction of a 200mm dia. pumping main from Golo to the treatment works at Elfahser</li> </ul>
1974	<ul style="list-style-type: none"> <li>- laying of a 200mm dia. Ring to reinforce the distribution system</li> <li>- Starting of consumer connections.</li> </ul>
1970- 1976	- drilling of groups of boreholes at Shagera El Wadi

1976	- connection of Shagera wells to the Golo head works by a 200mm dia. asbestos pipeline
1978	- construction of a 300mm dia. pumping main from Golo to El fasher
1980	- addition of pair of filters to the treatment works, treated water reservoir and a horizontal flow settling tank - Rising of the reservoir embankment 1.5m
1981	- installation of two more rapid filters. - Construction of central thermal power at Golo station.
	- Construction of a duplicate transmission line from Shagera El Wadi to Golo
1982	- Drilling of group of boreholes at Shagera El Goz - Construction of a 300mm pipeline between Shagera El Goz and El Wadi
1990	- Development of Shagera well fields and installation of submersible pumps
	- Construction of a 350mm dia. Transmission line form Shagera El Goz well field to Elfasher
1994	- Addition of a 3km. of 200mm dia. Pipeline to strengthen the distribution system.

## ***Chapter (3)***

### ***Methodology***

#### ***3.0 Introduction***

To meet the objectives of the study El fasher Town was visited for the purpose of collecting primary information and data relevant to the study. Samples from Shagera well field, Golo reservoir, the two hafirs, hand-dug wells around the Fula and hand-pumps in El fasher town are tested for the quality of these sources. Useful information and discussion were held with the key persons of various government departments; SDWC staff, officers of El fasher locality, manager of environmental health administration and statistical health authorities.

Useful secondary and basic data were availed from previous relevant studies in the area, particularly El fasher Water Supply conducted by Howard Humphreys and Partners (1981) and the similar one proposed by Hydromaster Inc.(2002).

#### ***3.1 Existing water supply facilities***

At present the water supply to El fasher town is derived from the following sources:

- i) Surface water sources collected in a reservoir and two adjacent Hafirs at Golo, 10km west of he town, (supply = 3000 m<sup>3</sup>/d)
- ii) Groundwater from the Nubian Sandstone of Shagera Basin at further 5 km to the west of Golo, about 18 boreholes have been constructed and installed with submersible pumps and allocated for the town water supply (yield = 7000 m<sup>3</sup>/d)
- iii) In addition to the above, two open lakes in the centre of the town known as the Fula, filled during the raining season,

used for garden irrigation, livestock watering, vehicle washing and recreation. The lakes usually dry up before the end of the dry season. There are also about four hand dug wells around the edge of the Fula form which water vendors fill their containers to be used for human consumption, notwithstanding the fact that it is highly polluted. Also there are more than 200 hand pumps distributed in the town, abstract water from the weathered basement that underlain the town terrain (yield = 1000 m<sup>3</sup>/d).

### ***3.1.1 Rainfall, runoff and surface water storage:***

The rainfall at El fasher area normally occurs during the months of June to October, the long term mean (1917 – 1999) is 284mm. analysis on the occurrence of various lengths of dry seasons have indicated that all years have more than 6 and less than 11 consecutive months during which rainfall is less than 20mm per month. Records show continuous general downward trend in the annual rainfall below the long term mean, the average, annual over the last 10 years has been only 190mm.

The seasonal runoff generated by wadi El Ku with its system of tributary wadis is the main source of replenishment of Golo reservoir and the Hafirs. The only gauging station on Wadi El Ku is at Sag El Naam and was established in 1977. No records available for this gauge, but local reports indicate that, since their construction, the reservoir and Hafirs have been fully replenished each year with a probability of 90%, therefore it can be suggested that sufficient runoff may be available to guarantee yearly storage capacity of 2.5Mm<sup>3</sup>.

### ***3.1.2 Golo Reservoir:***

The reservoir is roughly rectangular in plan with the larger sides parallel to the direction of flow, it is contained on three sides by a compacted earth fill embankment, the fourth side (up-stream) is formed by a low training embankment through which, in the rainy season, the wadi flow is channeled in a rectangular section concrete culvert. A side escape upstream of the inlet earth works directs excess surface flow away from the reservoir.

The embankments are constructed – since 1950 – from clay sand, with a 5 m wide crest road and slopes of 2:1 upstream and 3:1 downstream were used. The embankments were raised 1.5m in 1980 to increase the nominal storage to  $4\text{Mm}^3$  in order to offset the reduction due to accumulation of silts over years. Desilting has not been carried out since 1970 and the capacity of the reservoir is consequently considerably reduced, the depth of sediments appears to be not less than 1.5m. If this depth is assumed to have been deposited over the whole impounded area, a volume of  $2.5\text{Mm}^3$  is implied and the present storage would then be only  $1.5\text{Mm}^3$ .

### ***3.1.3 Hafir No. 1 (Capacity of $350.000\text{m}^3$ )***

It has been constructed in 1950; the storage area is semicircular in plan and is completely enclosed by a compacted earth fill embankment. The straight section of the embankment divides the Hafir from the reservoir; the floor level of the hafir is 1.5m below original ground level. The inside face is protected with a layer of stone pitching and there is a shelter belt of mature trees on the crest to reduce evaporation losses.

***3.1.4 Hafir No. 2 (650.000m<sup>3</sup> capacity):***

Hafir No. 2 was constructed in 1967; it adjoins the reservoir and Hafir No. 1, and is also roughly semi-circular in plan. Embankment crest level, floor level and top water level are identical to Hafir No. 1. The same material and embankments slopes have been used in its construction. No protection of masonry pitching on the inside face nor is there a shelter belt of trees planted.





### ***3.2 Water Requirements for Elfasher Town***

According to the information provided by the locality of El fasher Town, the present population (2004) of the town are about 250.000 person, comparing with the population at 2002 (about 200.000), the high growth is due to the settlement of the displaced rural people from their homes as a consequence of the present crisis in North Darfur state. It is clear that El fasher town grows more slowly than the national average, and this can be attributed to relative increase in importance of other towns (e.g. Nyala) and to effects of sahelian drought, which has affected North Darfur State more severely than it has in the South.

The requirement of the town is calculated for the given number of population (250000) with 2% rate of growth for 20 years divided into 5 years span in order to compare between the yearly demand and the annual recharge to the basin (26Mm<sup>3</sup>, H.M.Kaskous). The present consumption is 40 L/c/d and assumed to rise by 15 L every 5 years to be 100 L by the end of the 20 years. A peak demand factor of 1.5 is adopted.

### ***3.3 Water Supply Options and***

#### ***Water Resources Development Plan:***

A study made by Howard Humphreys and Partners (1983) on the water supply of El fahser had been carried out with a view to locate sustainable water sources for the supply of the town. Attention was focused on surface and groundwater sources which are relatively close to the town.

Many options have been examined for which was economically most attractive and which should form the basis for long term water development for El fasher, the evaluation was made considering the following costs:

- 1- Initial capital investment.
- 2- Regeneration cost.
- 3- Running cost

The study suggested that maximum utilization of the existing resources is economic option; the balance of demand would be met from the sag El Naam borehole field. Another suggestion is that the development of the surface water resources at Golo should be achieved by the construction of a third Hafir of  $1\text{Mm}^3$  capacity. Nothing has been done concerning these proposals until 2002 when Hydromaster Inc. has carried out a study to improve the water supply services of El fasher town on a sustainable manner within short, medium and long term basis.

The water supply options studied by Hydromaster Inc. aim to secure sustainable sources to El fasher town up to year 2032. The plans fall into two 5 years phases:

- i) The immediate to medium terms plan 2002 – 2007.
- ii) The medium to long term plan 2007 – 2032.

### ***3.3.1 The immediate to medium terms development:***

The plan aims to secure sustainable water supply source to El fasher up to 2007 and was comprised of:

- Development and optimization of surface and groundwater resources of Golo reservoir and Shagera basin respectively.
- Rehabilitation of the existing water supply facilities.
- Improvement of the water production, transmission, storage, quality and distribution network.
- Development of operation and management plan for conjunctive use of the two sources.

### ***3.3.2 The long Term Water Supply Plan:***

This plan draws on the development of Sag El Naam basin. The plan is to augment Shagera and Golo water resources by the end or before the first 5 year plan; it requires the following water works:

- i) Construction of an 800mm pipeline from Sag El Naam to the town.
- ii) Installation of at least 5 – stand water points at reasonable intervals between Sag El Naam and El fasher.
- iii) Drilling of 18 wells near Sag El Naam village, production capacity of 150 m<sup>3</sup>/h.
- iv) Construction of groundwater reservoirs.
- v) Installation of telecommunication system and buildings

### ***3.4 Improvement of water supply for scattered villages around Golo and Shagera area.***

#### ***3.4.1 Introduction:***

Since all studies are focusing to Sage El Naam Basin as the reliable source to meet the present and future demand of drinking and domestic water supply of El fasher town and its suburban, so, the present source – Golo and Shagera basin – must not be abandoned completely, it can be assessed for supplying potable water to the scattered villages in the vicinity as well as watering their livestock.

Shagera source doesn't need further treatment rather than disinfection which can be achieved by some amendments in Shagera El Qoz pumping station, and rehabilitate the elevated tank which was mainly constructed to maintain head for the three water points now used to supply the inhabitants of the scattered villages around Shagera area.

The surface water stored behind Golo dam and the two hafirs is not safe for drinking. A safe and convenient drinking water supply is essential to human health and the well being of the community. To obtain safe water, usually some form of treatment is needed to convert the water in such a way that it becomes safe and pleasant to drink; this may be achieved through slow sand filtration. Filtration technique is an effective, low-cost purification process that produces attractive and safe water to drink, its operation and maintenance is further more cheap and simple, although slow sand filtration plant occupy a fairly large area of land and require additional labor input for cleaning of the filters, but it makes no problem in Golo area.

#### ***3.4.2 Existing Situation of Rural Villages:***

Rural villages all over North Earful Suffer from getting their drinking water, partly due to extensive water deficit due to low rainfall and partly due to the remoteness of the source of water. It is clear that many villages are founded especially due to the presence of a source of water; either a hafir, a dam or a wateryard. The present increase in numbers of livestock and the expansion in farming made by the displaced rural settlers have caused additional burden on the existing water sources and deteriorated their efficiencies.

Villages around Golo and Shagera are luckily enough to be focused for improving their water supply system since Golo Dam and Shagera well field are much more valuable than to be abandoned after Elfasher water supply was solved from Sag El Naam basin. Villages in Shagera area are now fed through public stand posts (Kiosks), the system can be improved in the future to network system.

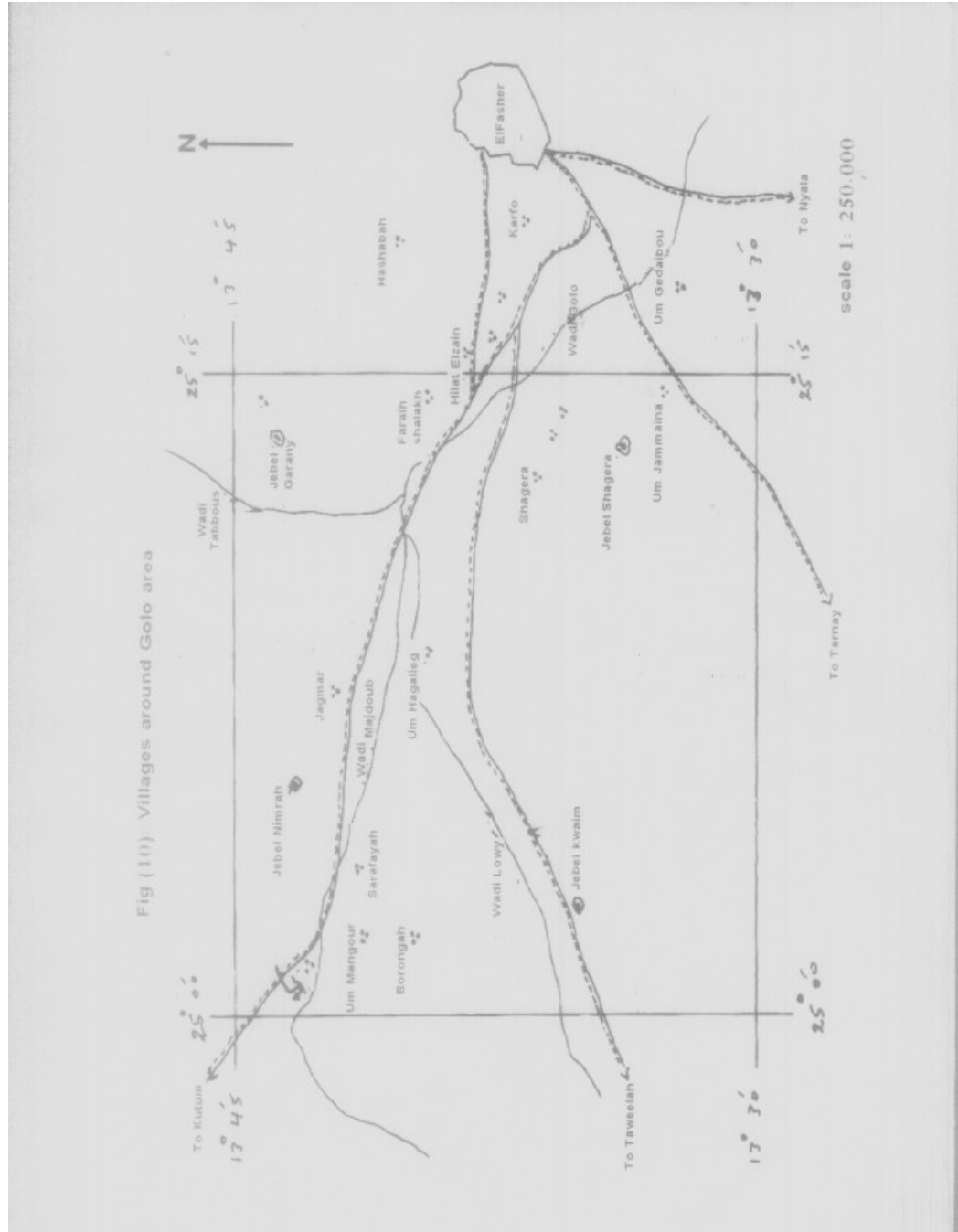
### ***3.4.3 Population and water requirements:***

Due to the present crisis which happened in North Darfur, many of the rural people have been displaced from their homes, and are expected to settle around the villages in Golo area to farm the promising agricultural land and the availability of drinking water. Table (12) shows some villages – around which displaced people will settle – and supposed to be supplied by common stand posts fed from Golo head works, a map attached. (Information was drawn from El fasher Rural Council.)

***Table (3.1)***  
***Villages in Golo Area***

<b>No</b>	<b>Village Name</b>	<b>No of families</b>	<b>Inhabitants</b>
1	Jugmar	50	395
2	Farai shalakh	150	1247
3	Hill at El Zain	100	723
4	Um Jummanah	85	475
5	Kargo	60	442
6	Hashaba	85	430
7	Um Gedaibo	162	1020
8	Um Hagalieg	231	1281
9	Golo A	75	405
10	Golo B	190	1240
11	Golo C	207	1242
	Total		8900

**Fig. (3.2)**  
***Villages to be fed from Golo Head Works***



## ***Chapter Four***

### ***Results and Discussion***

#### ***4.1 Assessment of Elfasher water supply:***

##### ***4.1.1 Quantity:***

The present sources of water supply to Elfasher town are from:

- Golo reservoir and the two hafirs (surface water).
- 18 bore holes at shagera well field (ground water).
- The Fula, hand dug wells and hand-pumps

The total yield is about 11000 m<sup>3</sup>/d which is not satisfactory for the present requirement of the town (22500 m<sup>3</sup>/d)

Golo Dam as one of the main sources has its own problems such that:

- 1- Accumulation of silts over years.
- 2- Most of the wadis in the catchment of Golo change their courses every year due to the advancement of sand dunes southwards by northerly winds enhanced by drought episodes. A lot of work should be done before rain to lead the course to the main entrance of the dam.
- 3- Decrease of rainfall intensity for the last three decades leads to a decrease in the amount of surface runoff giving a probability of not filling Golo Dam. It happened during the year 2001.
- 4- High evaporation rates (9.8 mm/d) [Sudan Meteorological Service estimations of open surface evaporation) decrease the storage amount.

The groundwater recharge to the sandstone in shagera basin depends mainly on rainfall. Either direct infiltration or from runoff during periods of floods in the wadis.

The Fula as well is to be filled only when rain falls. Hand-dug-wells also are charged through floods originated by rain.



#### **4.1.2 Water Quality of the Present Sources:**

20 samples from the present sources have been tested for turbidity, total dissolved solids (TDS) and hardness; the results were discussed hereunder:

**Table (4.1)**  
**Test of Surface water Sources**

No	Source of Sample	Turb. NTU	Remarks	TDS Mg/L	Remarks	Hardness Mg/L as CaCO <sub>3</sub>	Remarks
1	Golo Reservoir	227	V.Turbid	160	Good	207	Hard
2	Hafir No. 1	22.3	Accepted	120	Good	132	Moderately hard
3	Hafir No. 2	36.1	Turbid	120	Good	147	Moderately hard

The WHO standards which most drinking water supplies should conform to are such that:

5 NTU is the max permissible value for turbidity,

500 mg/L is the max recommended concentration for TDS,

and for Hardness: Soft < 50 mg/L as CaCO<sub>3</sub>

Moderately hard 50 – 150 as CaCO<sub>3</sub>

Hard 150 – 300 CaCO<sub>3</sub>

Very hard > 300 CaCO<sub>3</sub>

∴ The above results show that the surface source needs treatment before supplying to consumers, although currently the water drawn from the two hafirs is being mixed with water coming from Shagera El Wadi boreholes at Golo head works and then transported to El fasher station from where it is going to be distributed to the consumers.

**Table (4.2)****Test of Ground Water Sources:**

<b>Index</b>	<b>Source of sample</b>	<b>Turbidity NTU</b>	<b>Remarks</b>	<b>TDS Mg/L</b>	<b>Remarks</b>	<b>Hardness Mg/L as CaCo<sub>3</sub></b>	<b>Remarks</b>
1	Borehole No. 4	5.64	Good	340	Accepted	174	Hard
2	Borehole No. 6	3.29	Good	440	Accepted	288	Hard
3	(Qz) No. 9	16.9	Accepted	220	Accepted	180	Hard
4	(Qz) No. 10	4.93	Good	270	Accepted	195	Hard
5	(Qz) No. 12	9.43	Accepted	290	Accepted	219	Hard

It is clear that the tested samples indicate that the ground water source conforms to WHO drinking water standards and although the water needs softening, while the TDS concentrations are accepted.

**Table (4.3)****Test of Hand Pups**

<b>No.</b>	<b>Source of sample</b>	<b>Turbidity NTU</b>	<b>Remarks</b>	<b>TDS Mg/L</b>	<b>Remarks</b>	<b>Hardness Mg/L as CaCO<sub>3</sub></b>	<b>Remarks</b>
1	Teamanat	6.63	Accepted	460	Accepted	336	Very hard
2	Kafoat	29.5	Turbid	900	Not recom	723	Very hard
3	El Thowrah south	23.4	Turbid	770	Not recom	532	Very hard
4	Abu Shoak	6.53	Accepted	420	Accepted	240	Hard
5	El Wohdah	8.04	Accepted	600	Not recom	492	Very hard

The above results show that water extracted by hand pumps is not suitable for drinking, they are not conforming to WHO standards, very hard water, containing great amount of total dissolved solids except the hand pumps at Abu Shoak area , it is a new extension and has no pipeline, only depending on hand pumps.

**Table (4.4)**  
**Test of Hand Dug Wells**

<b>No.</b>	<b>Source of sample</b>	<b>Turbidity NTU</b>	<b>Remarks</b>	<b>TDS Mg/L</b>	<b>Remarks</b>	<b>Hardness Mg/L as CaCO<sub>3</sub></b>	<b>Remarks</b>
1	Hager Gaddoh	2.9	Good	810	Not recom.	558	Very hard
2	Ali Badeen	1.11	Good	400	Accepted	375	Very hard
3	Oil factory	4.62	Good	870	Not recom.	705	Very hard

It is clear that the water extracted from hand dug wells is not suitable for drinking; it is very hard water containing dissolved solids greater than the recommended value, so they should be abandoned at once.

Two samples taken from under ground tanks at El fasher treatment station were tested, this is where water from shagera El Qoz mix with water from Golo head works just before being send to the consumers. Other two samples taken from the distribution network were tested, and the results are as follows:

**Table (4.5)****Test at treatment Station and Distribution Network**

No.	Source of sample	Turbidity NTU	Remarks	TDS Mg/L	Remarks	Hardness Mg/L as CaCO <sub>3</sub>	Remarks
1	Treatment station Tank No. 3	28.4	Turbid	330	Accepted	213	Hard
2	Treatment station tank No. 4	24.5	Accepted	330	Accepted	225	Hard
3	Network khorsial	8.18	Accepted	240	Accepted	237	Hard
4	Network Kafoat	16.7	Accepted	310	Accepted	219	Hard

**4.1.3 Comments:**

The samples which have been tested for the quality of the present sources indicate that the surface sources contain turbidity much higher than the allowable concentration (227 NTu); the water needs to be treated before supplying to the consumers.

Groundwater from Shagera basin is hard water (174-288) mg/l as CaCO<sub>3</sub>), hardness can be decreased by mixing groundwater with the treated surface water from Golo Dam.

Water extracted by hand-pumps is very hard water, with TDS concentration greater than the max. Recommended value by WHO, the same for the hand-dug-wells.

Viewing all the above demerits, attention has been focused on Sag El Naam as a very safe water source to meet the present and future demand of drinking and domestic water supply of Elfasher town.

#### 4.1.4 Water Demand Projection:

Since water consumption represents the water actually supplied to the consumers and registered by the consumer meters, the consumption is probably less than it would be if water availability is restricted, and water demand is the total input to the system from the head works.

The present population is projected from 2004 up to 2024 (for 20 years) at a constant growth rate of 2%, i.e.

$$P_n = P_o (1+r)^{n-1}$$

$$P_o = 250000 \text{ persons} = P_{2004}$$

$$r = 2\%$$

$$n = 20$$

$$P_n = P_{2024}$$

$$\therefore P_{2024} = 250000 (1+0.02)^{20-1} = 364000 \text{ parson.}$$

Present water consumption	40 L/c/d
Consumption after 20 years	100 L/c/d
20% of the requirement as water not accounted for (losses, ...)	20%
30% of the requirement for institutions and industries	30%
peak demand factor	1.5
$\therefore$ Consumption = 364.000 x 100 =	36,400 m <sup>3</sup>
50% other requirement	18,200
Total daily requirement	54,600
Peak demand 54.600 x 1.5 =	81,900
Qd =	Say 82.000 m <sup>3</sup> /d

**$\therefore$  Water deficit = (daily demand) – (yield from present sources)**

**Yield from present sources =**

**(supply of surface water sources) + (yield from ground water sources) +  
(Contribution of the Fula, hand dug wells and hand pumps)**

$$= 3000 + 7000 + 1000$$

$$= 11,000 \text{ m}^3/\text{d}$$

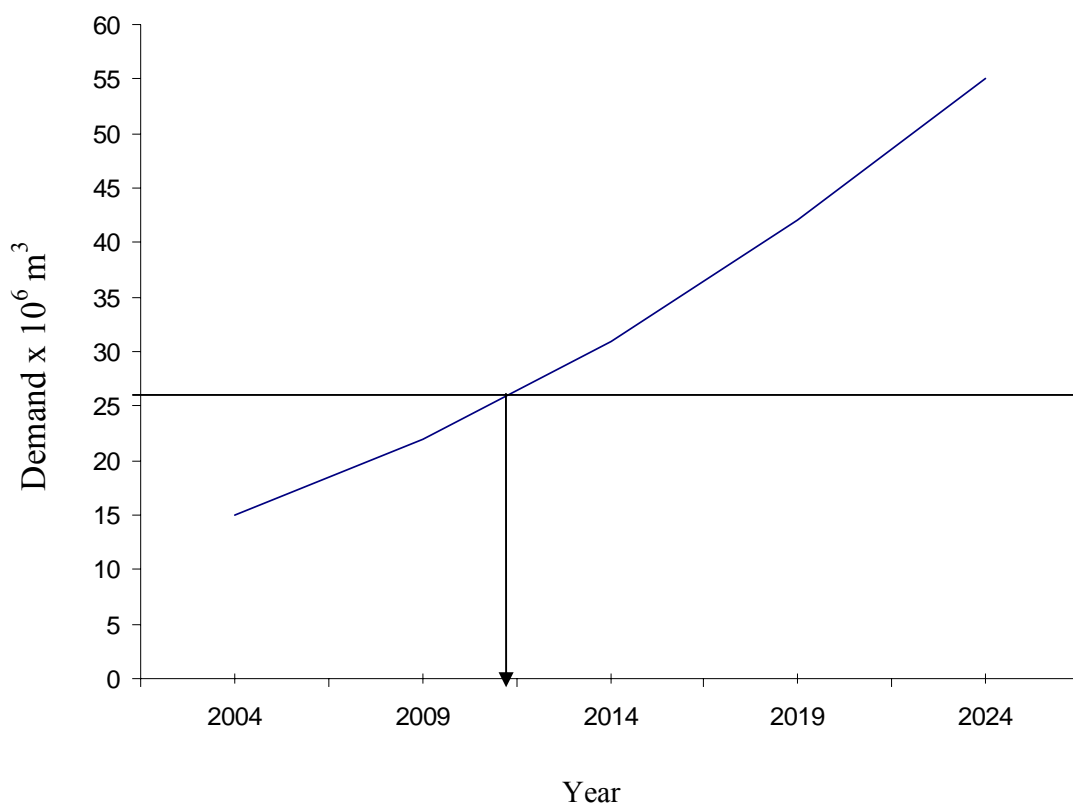
$$\therefore \text{Water deficit} = 54600 - 11,000 = 43600 \text{ m}^3/\text{d}$$

This deficit should be covered through the execution of Sag El Naam Water Supply Project.

**Table (4.6)**  
**Water demand per year**

<b>Year</b>	<b>Pop. X 10<sup>3</sup> persons</b>	<b>Requirement L/c/d</b>	<b>Demand / year x 10<sup>6</sup>m<sup>3</sup></b>
2004	250	40	15
2009	270	55	22
2014	299	70	31
2019	330	85	42
2024	364	100	55

**Fig. (4.1)**  
**Demand Curve**



From the demand curve (Fig.4.1) it is clear that the water demand can be discharged from the annual recharge (26Mm<sup>3</sup>/year,Kaskous H.M. 1991) this continues up to the year 2012, after that year the demand will be more than the annual recharge, the difference should be covered from the quantity in storage within the basin of Sag El Naam. Another suggestion to increase the annual recharge by obstructing Wadi El ku somewhere within the area of Sage El Naam to allow spreading of runoff in order to facilitate its infiltration down ward to the basin.

## ***4.2 Design of a rural water treatment plant***

### ***4.2.1 Population Projection and water demand***

No. of Inhabitants	= 8900 person
If 30% was anticipated displaced people	= 2760
Total	= 11570
Annual growth	= 2%
Design period	= 10 years
∴ The No. of inhabitants after 10 years	= $11570 (1+0.02)^{10-1}$
	= 13827
	say 14000 people

### ***Water Demand:***

Water demand is the total input to the system from the head works.

Total demand = demand by consumers + water not accounted for (losses)

According to WHO regulations, the requirement is estimated at a consumption rate of 50L/C/d with a peak demand factor of 1.5, all other requirements including livestock watering are assumed 40% of the

consumption rate for the design of the slow sand filter, the design period is 10 years.

Consumption requirements	$= 14000 \times 50 \times 10^{-3}$	$= 700 \text{ m}^3/\text{d}$
Other requirements is 40%	$= 40 \times 700 / 100$	$= 280 \text{ m}^3/\text{d}$
Total requirement	$= 980 \text{ m}^3/\text{d}$	
	say $1000 \text{ m}^3/\text{d}$	
Peak demand	$= 1.5 \times 1000$	$= 1500 \text{ m}^3/\text{d}$

Given that the future demand of El fasher town was expected to be met from Sag El Naam basin, and the surface water supply from Golo is to be treated and supplied to the rural people in the area of Golo, there might be a surplus amount as:

Supply of surface water source	$= 3000 \text{ m}^3/\text{d}$
Peak demand of the rural people	$= 1500 \text{ m}^3/\text{d}$
$\therefore$ Surplus amount	$= 1500 \text{ m}^3/\text{d}$

By this surplus amount, the rural people may have chance for vegetation plantation as well as animal growing for exporting purposes.

There is available area for the above activities that can be fed directly from the Hafirs.

#### ***4.2.2 Design of Plain Sedimentation Tank:***

The surface loading is governed by the capture of the suspended particles.

The desired surface loading is maintained by:

- Designing the tank capacity.
- Detention period.
- Tank depth.

The necessary tank capacity (C) is dependent on the detention period (T) and the rate of flow of water Q, i.e.:



$$T = C/Q$$

If  $T = 4 - 6$  hrs

$$Q = 1500 \text{ m}^3/\text{h}$$

Assuming 10 working hours a day, then

$$Q = 1500/10 = 150 \text{ m}^3/\text{d}$$

and  $C = T Q$

$$= 4 \times 150 = 600 \text{ m}^3$$

Select rectangular tank, ratio between length to width 2:1, fix the tank depth to be 3m

$\therefore$  area of tank = capacity / depth

$$= 600 / 3 = 200 \text{ m}^2$$

$$\text{length} = 2 \times \text{width}$$

$$\text{area} = \text{length} \times \text{width} = 2 (\text{width})^2 = 200 \Rightarrow$$

$$W = 10 \text{ m}$$

$$L = 20 \text{ m}$$

$\therefore$  Tank dimension 10m x 20m x 3m

The tank efficiency is much affected by various cross currents and disturbances due to turbulence at inlet and outlet.

$\therefore$  Choose inlet with baffle walls with multiple openings,

Choose submerged outlet with multiple openings.

Fig. (4.3) shows the inlet and outlet arrangements.

#### ***4.2.3 Design of slow sand Filter:***

$$\text{Total flow required} = 1500 \text{ m}^3/\text{d}$$

$$\text{rate of filtration} = 6000 \text{ L/m}^2/\text{d}$$

$$\text{area of filter bed} = \text{flow} / \text{rate} = (1500 / 6000 / 10^{-3}) = 250 \text{ m}^2$$

$\therefore$  Provide 2 No. of slow sand filters each of 12.5m x 20m, one of them as stand by filter.

A) Filter bed:

Provide 90 cm sand bed

- i) top 30cm with 0.3mm (effective size)
- ii) next 30cm with 0.35 mm (effective size)
- iii) bottom 30cm with 0.4mm (effective size)

B) Gravel bed (60cm thickness)

- i) top 20cm with 3 mm (effective size)
- ii) next 20 cm with 5 mm (effective size)
- iii) bottom 20Cm with 7.5mm (effective size)

Use under drains of perforated pipes for collection of the filtered water. Fig (4.2)

#### ***4.2.4 Design of Clear water tank:***

Provide capacity of one day demand = 1500m<sup>3</sup>

Choose concrete or masonry tank of dimensions as:

$$20\text{m} \times 25\text{m} \times 3\text{m}$$

#### ***4.2.5 Design of pipe line and pump:***

i) Pipe line design:

$$Q \text{ required} = 150 \text{ m}^3/\text{h} = 0.042 \text{ m}^3/\text{sec}$$

assume velocity of water through the pipe = 1.5 m/sec

$$Q = \text{area} \times \text{velocity}$$

$$\begin{aligned} \therefore \text{Pipe x section} &= Q/\text{velocity} = (0.042 / 1.5) \\ &= 0.028 \text{ m}^2 \end{aligned}$$

$$A = \pi D^2/4$$

$$0.028 = (\pi D^2) / 4 \Rightarrow D = \sqrt{\frac{4 \times 0.028}{\pi}} = 0.19\text{m}$$

$$\text{Take } D = 200\text{mm}$$

$$\text{actual velocity } Q/A = (0.042 \times 4) / (0.2)^2 \times \pi = 1.3\text{m/s}$$

## **ii) Pump selection:**

If the farthest stand – post is to be 10 km from the head works, the frictional head loss through pipe is given by:

$$hf = f L/D (v^2/2g) \text{ (Darcy Weisbach)}$$

**Where:**

hf: frictional head loss through pipe

f: friction factor(function of Reynolds No.)

L: distance of the farthest stand post from head works

D: pipe diameter

V: velocity of water through the pipe

g: acceleration due to gravity.

The friction factor f is given by:

$$\frac{1}{\sqrt{f}} = 1.8 \log R - 1.5186 \text{ (Colebrook's equivalent equation for turbulent}$$

flow in smooth pipe) [Fluid Mech. Dr. A.K. JAIN])

$$R = VD/\nu$$

R: Reynolds No.

$\nu$ : Kinematic viscosity of water ( $10^{-6} \text{ m}^2/\text{s}$ )

$$R = 1.3 \times 0.2 / 10^{-6} = 260000$$

$$\frac{1}{\sqrt{f}} = 1.8 \log (260.000) - 1.5166 = 8.228$$

$$\Rightarrow f = 0.0147$$

$$\cong 0.015$$

$$\therefore hf = 0.015 \times \frac{10^4}{0.2} \times \frac{1.3^2}{2 \times 9.81} = 65m$$

- if the slope of ground is taken as 1m : 1 Km
- the service reservoir is 3m above ground level

$$\therefore \text{Static head loss } h_p = 10 \times 1 + 3 = 13\text{m}$$

$$h_f + h_p = 65 + 13 = 78\text{m}$$

$$\text{Add 10\% for losses due to fittings and others} = 0.1 \times 78$$

$$= 7.8$$

$$\therefore \text{Total head} = 78 + 7.8 = 85.8$$

$$\text{say } 90\text{m}$$

$$\text{Power required to drive the pump is } = \gamma_{\text{wat}} \times Q \times H_t$$

$$\gamma_{\text{wat}} = \rho_{\text{wat}} \times g = 1000 \times 9.8$$

$$H_t = 90\text{m}$$

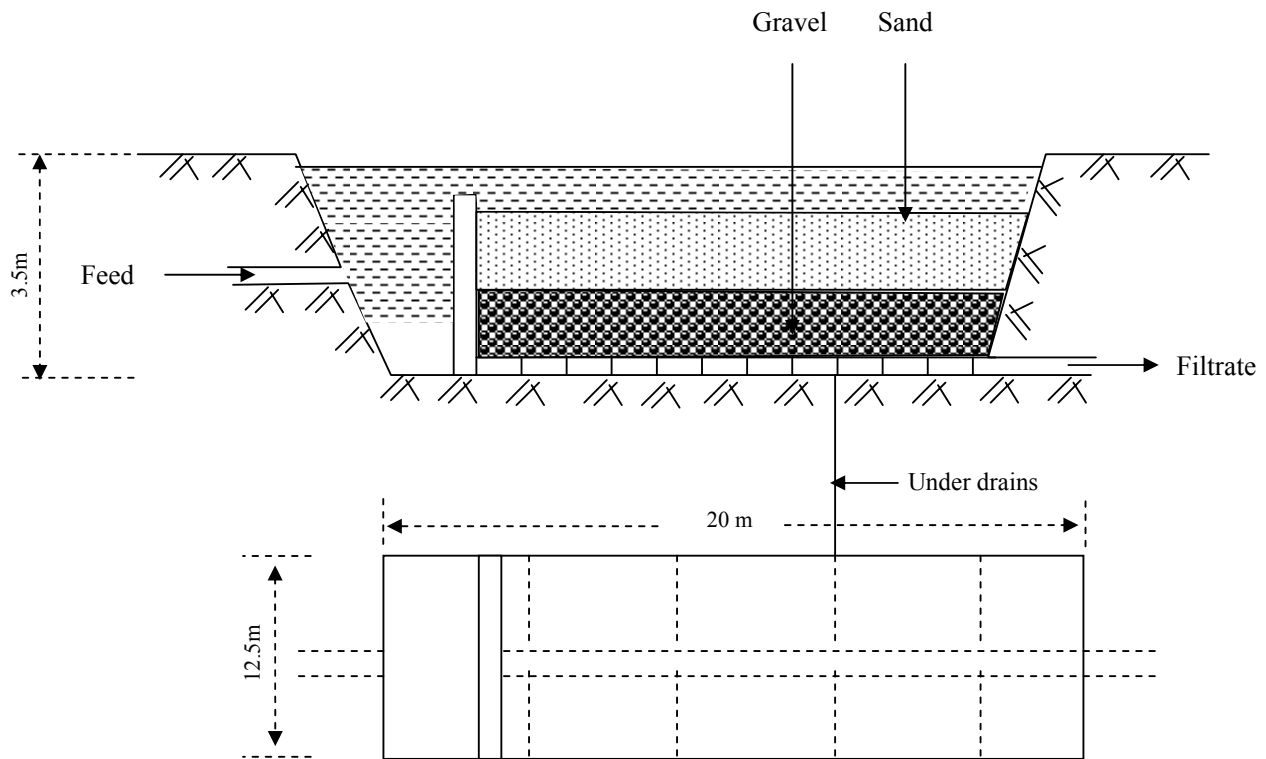
$$Y = \text{motor efficiency} = 70\%$$

$$\therefore \text{Power} = 1000 \times 981 \times 0.042 \times 90 / 0.7$$

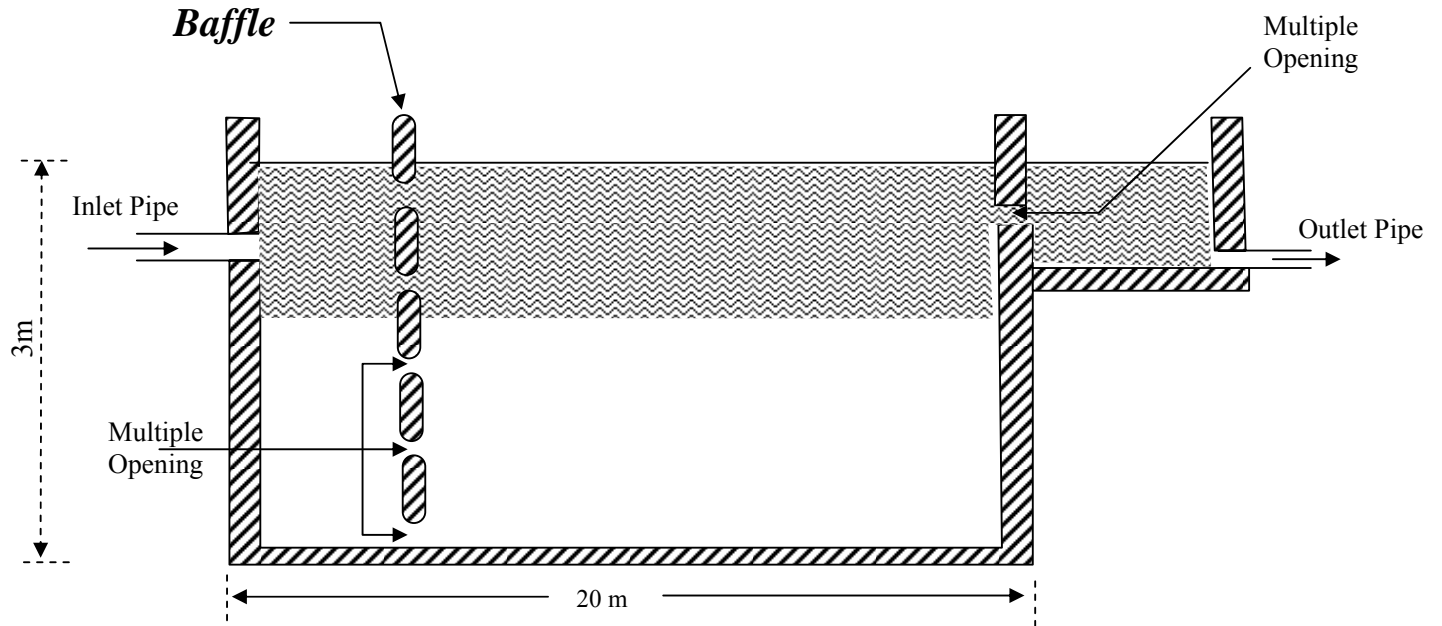
$$= 53 \text{ kW}$$

$$= 70 \text{ HP}$$

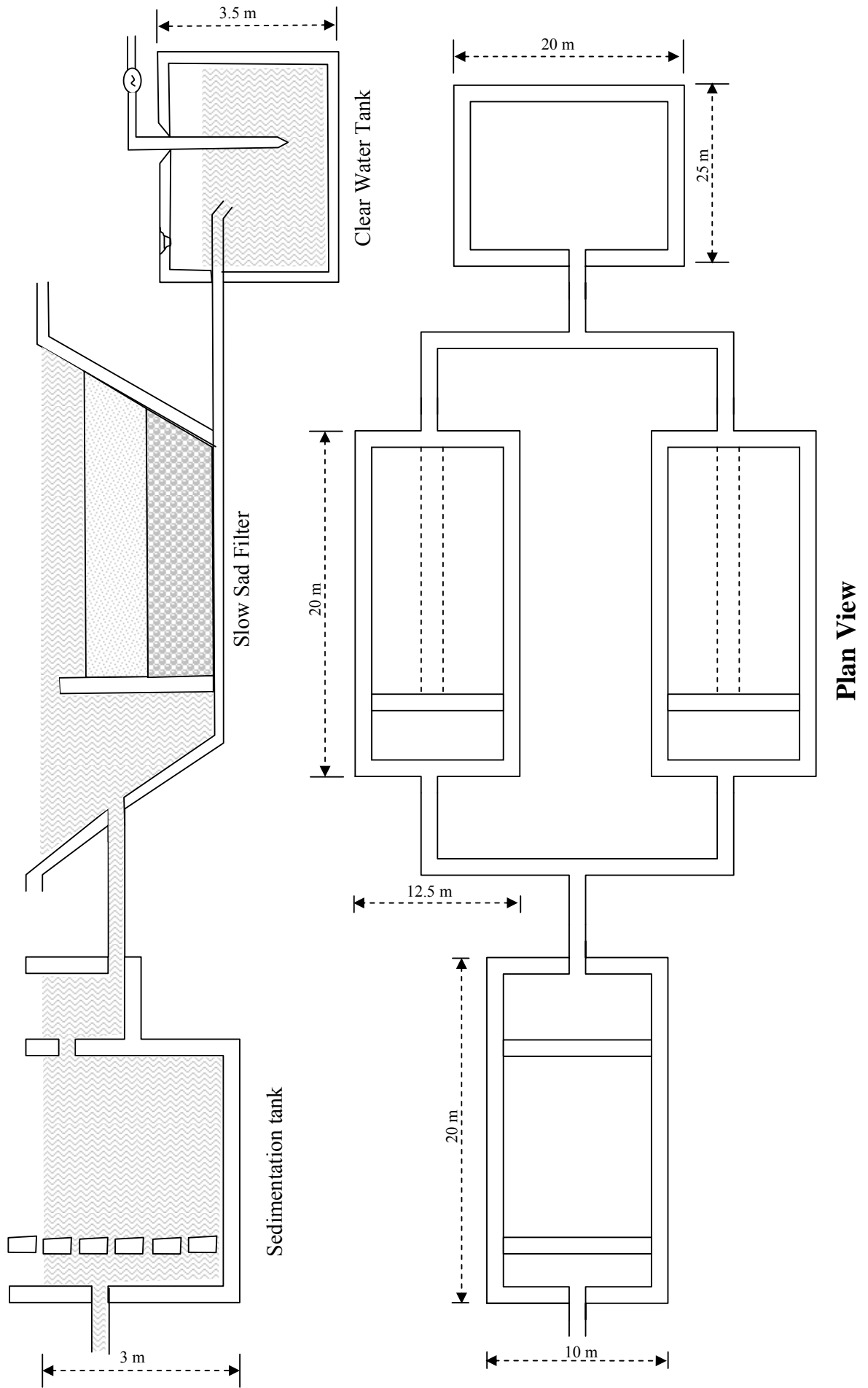
**Fig. (4.2)**  
**Slow Sand Filter**



**Fig. (4.3)**  
**Sedimentation Tank**



**Fig. (4.4)**  
**Rural Water Treatment Plant**



### 4.3 Cost of the Project:

If the rural treatment plant is assumed to be constructed from reinforced concrete floors (0.15m thick) and masonry walls (0.4m thickness) for the sedimentation tank, slow sand filters and clear storage tank, as follows:

Item	Sedimentation tank	Slow sand filter	Clear storage tank	Total
Concrete (m <sup>3</sup> )	30	75	75	180
Masonry (m <sup>3</sup> )	72	156	116	344

**Table (4.7)**

#### Bill of quantities

Index	Quantity	Unit	Description	Rate SD	Amount x 10 <sup>6</sup> SD
1	180	m <sup>3</sup>	Reinforced conc	75000	13.50
2	344	m <sup>3</sup>	Masonry work	40.000	13.76
3	10.000	m <sup>3</sup>	UPVC pipe mm dia	5000	50.00
4	3	No	Service reservoir	3000.000	9.00
5	2	No	Centrifugal pump Q, h, P	4000.000	8.00
Total					94.26
Add 10% for unforeseen					9.426
<b>Grand total</b>					<b>103.686</b>

One hundred & three million, six hundred and eighty six thousands SD.  $\approx$  400.000 USD (*Four hundred thousands US dollars*).

(Rates are based on current market rate).



**Cost Effectiveness:**

It is agreed that the presence of a safe and reliable source of water is an essential are-requisite for the establishment of a stable community. The cost of the proposed project (Rural Water Treatment Plant) is about 400.000USD, it is an affordable cost in viewing to locate a sustainable water supply system for a community and is an appreciable contribution in the well being of their life. The community should have to participate with the government in preparing the initial capital as well as in the running of the project.

#### ***4.4 Computer Program***

```
Parameter (Pi = 3.14, rho = 1000, g = 9.81)
Character*3 ans
C
C --- Read pipeline information
C
Print*, 'Enter the required discharge in cumecs'
Read*, Qreq
Print*, 'Enter the assumed velocity of water in m/sec'
Read*, Vas
Print*, 'Enter the length of the pipeline in m'
Read*, xl
C
C---Calculate the flow area, pipe diameter and the actual velocity
C
Area = Qreq/Vas
D = sqrt(4*area/Pi)*1000
Vac = Vas
Write(*,5)D
5 format (5x, 'the calculated diameter is', F10.3, 1x, 'mm')
Print*, 'Do you want round the diameter'
Print*, 'Enter Yes or No'
Read(*,'(a3)')ans
If(ans(:1).eq.'y'.or.ans(:1).eq.'Y')then
Print*, 'Enter New value for D in mm'
Read*,D
D = D/1000
Area = Pi/4*D**2
Vac = Qreq/Area
Print*,area,vac
Endif
Write(*,8)Vac
```

```

8 format (2x, 'The actual velocity is', F10.3, 2x, 'm/sec')
C
C --- Design the pump
C
xNu = 1/100000
R = Vac*D/xNu
Write(*,9)R
9 format(2x, 'The Reynolds Number is', F10.3)
f = 1/(1.8*log10(R)-1.5186)**2
hf = f*x1/D*Vac**2/(2*g)
hp = x1/1000+3
he = 0.1*(hf + hp)
ht = hp + hf + he
Write(*,10)ht
10 format(2x, 'The calculated total head is', F10.3 1x, 'm')
Print*, 'Do you want to round the total head'
Print*, 'Enter yes or No'
Read(*,'(a3)')ans
If(ans(:1).eq.'y'.or.ans(:1).eq.'Y')then
Print*, 'Enter New value for ht'
Read*,ht
endif
print*, 'Enter the pump efficiency'
read*,efc
power = rho*g*Qreq*ht/efc/1000
write(*,15)power
15 format (2x, 'the required power is', f10.3, 1x, 'kw')
Stop
End

```

### **The results**

The required discharge is	0.042 Cumecs
The assumed velocity is	1.500 m/sec
The pipeline length is	10000.000 m
The calculated diameter is	188.862 mm
He corrected flow area is	0.031 sq.m
The actual velocity is	1.338 m/sec
The Reynolds Number is	267515.900
The friction coef. F is	0.015
The hp value is	13.000 m
The he value is	7.998 m
The calculated total head is	87.976 m
The corrected total head is	90.000 m
The pump efficiency	0.700
The required power is	52.974

## ***Chapter (5)***

### ***Conclusion and Recommendation***

#### ***5.1 Conclusion:***

##### ***5.1.1 Assessment of Elfasher Water Supply:***

Elfasher is the most important town in North Darfur State; it provides a market to the surrounding area and other services such as airport, health and education. The town lies in tropical semi-arid climatic region, the frequent sahelian drought events enhanced the process of desertification and forced rural people to settle on the extremes of the town. Shortage of water has constrained industrial activities.

Importance of the town leads the central government to think about improving the water supply system which mainly depends on the Fula and hand-dug-wells around it. Construction of Golo reservoir started early in 1950s, investigations in Darfur region made by hunting MacDonald during 1968 and 1972 led to the delineation of Shagera and Sag El Naam aquifers, they are available groundwater resources for Elfasher town.

A treatment plant and a distribution system (kiosks) were constructed in 1960 and has been expanded in stages. Ground water from Shagera basin is extracted since 1976; the productivity is increased by erection of submersible pumps at the bore holes in 1990.

The present sources of water supply to El fasher can not satisfy water requirements in quantity and quality, SDWC is currently planning to supply the town from Sag EL Naam basin on the long term.

The future demand for drinking and domestic purposes is projected for the coming 20 years as:

- Present population	250000
- Rate of growth	2%
- Projected population	364000
- Present water consumption	40L/C/d
- Present requirement	22500m <sup>3</sup> /d
- Assumed future consumption	100L/C/d
- Projected demand	546000
- Peak demand factor	1.5
- Other requirements	50%
- Yield of present sources	11.000m <sup>3</sup> /d
- Deficit	43600m <sup>3</sup> /d

The deficit should be covered through the execution of Sag El Naam Water Supply Project.

***5.1.2 Options Available for Water Supply of Elfasher Town and its Suburbs:***

- 1- Max. Utilization of the existing resources, the balance of demand would be met from Sag El Naam Boreholes.
- 2- Development of surface water resources at Golo by construction of a third hafir of 1Mm<sup>3</sup> capacity.

Evaluation with regard to initial, regeneration and running costs proved that No. 1 is economic option. The plans fall into 5 years phases:

- a. The immediate plan, and is comprised of:
  - 1. Development and optimization of surface and groundwater resources at Golo reservoir and Shagera Basin respectively.
  - 2. Rehabilitation of the existing water supply facilities.
  - 3. Improvement of water production, transmission, storage, quality and distribution network.
  - 4. Development of operation and management plan for conjunctive use of the two sources.
- b. The long term plan; it is to augment Golo and Shagera water resources by the end or before the first 5 years. The plan draws on the development of the Sag El Naam basin, it requires:
  - 1. Construction of an 800mm pipeline from Sag El Naam to Elfasher.
  - 2. Installation of at least 5 stand water points between Sag El Naam and Elfasher.
  - 3. Drilling of additional high production wells.
  - 4. Construction of ground water reservoirs.
  - 5. Installation of telecommunication system and buildings.

### ***5.1.3 Rural Water Treatment Plant:***

A plant for treating the surface water stored behind Golo Dam and the two hafirs has been designed to supply villages around Golo area with potable and safe drinking water, the treatment of water should be carried out through slow sand filtration. The demand is projected as:

- Design period	10 years.
- No. of population	14000
- Consumption rate	50 L/C/d
- Other requirements	40%
- Projected demand	1500 m <sup>3</sup> /d

A simple and sustainable plant is chosen, it consists of:

- Presedimentation tank 10 × 20 × 3m dimensions.
- Slow sand filter with 250m<sup>3</sup> effective area.
- Clear water storage tank volume of 1500 m<sup>3</sup>
- Pump unit and a pipeline 200mm dia.
- Distribution system for public water points with storage reservoirs.

The estimated cost of the project is about 103,686,000 (one hundred and three million, six hundred and eighty six thousand SD).

A computer programmed was carried for the design of the main pipe and the pumping unit.



### ***5.2 Recommendations:***

1. Conduction of a comprehensive hydro geophysical survey to Shagera basin to determine whether it may or not satisfy the future requirement of Elfasher, Shagera is closer to the town than Sag El Naam.
2. Arrangements should be done in Golo head-works to facilitate the groundwater of Shagera El Wadi to be mixed with the treated surface water at Elfasher station in order to improve the quality of the water.
3. Carrying out frequent water quality monitoring for sources and after treatment.
4. Disilting of the reservoir and the two hafirs can be carried out regularly every 5 years if possible.
5. Villages around Golo area can be put in forms of big settlements to facilitate individual house connections.
6. Water Kiosks can be installed for the supply of local population between Sag El Naam and Elfasher.

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